

**UPDATING AN INFRASTRUCTURE MANAGEMENT
INFORMATION SYSTEM ARCHITECTURE: A GUIDE FOR
NAVY PUBLIC WORKS OFFICERS**

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A report submitted to the Graduate Committee
Of the Department of Civil Engineering in
partial fulfillment of the requirements
for the Degree of Masters of Engineering

Texas A&M University
3 April 2000

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AD NUMBER	DATE 15 JUNE 2000	DTIC ACCT NOT
1. REPORT IDENTIFYING INFORMATION		REQUESTER: 1. Put your mailing on reverse of form 2. Complete items 3. Attach form to request mailed to DTIC. 4. Use unclassified information only 5. Do not order documents for 6 to 8 weeks
A. ORIGINATING AGENCY Naval Postgraduate School, CA 93943		
B. REPORT TITLE AND/OR NUMBER Updating An Infrastructure Management Information System Architecture: A Guide For Navy Public		
C. MONITOR REPORT NUMBER By: Kevin Bartoe, Thesis, Texas A&M U, April 2000		
D. PREPARED UNDER CONTRACT NUMBER N62271-97-G-0043		DTIC: 1. Assign AD Number 2. Return to requester
2. DISTRIBUTION STATEMENT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED		

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DTIC Form 50
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Abstract

The rapid advance of computer technology has been both a bane and a boon for public works organizations. Computers have allowed for enhanced communication, faster information processing, and detailed graphical imaging. They have also led to the formation of “islands of data” on unconnected networks, proprietary software systems that do not communicate with each other, and challenges in retaining skilled personnel in information technology.

Civil Engineer Corps Officers in the United States Navy are responsible for managing the force’s base infrastructure and public works organizations. The US Navy operates more than 140 bases worldwide with a plant value over \$140 billion. Public works operations have seen improvements in their infrastructure information management over the past two decades. Computers and network systems play a large roll in the success of collecting, managing and using facilities data to make better infrastructure decisions. Information technology (IT) continues to improve at a torrid pace. Public works organizations that operate unaware of the potential successes and failures in the IT field will not benefit from its advances.

This report is intended to be a guide for Navy Public Works Officers to the current trends in updating an IT system architecture within a facilities management organization. The concept of Asset Management is introduced as a strategy for selecting project alternatives using IT tools. The basics of internet and intranet operations are discussed including intranet operations, new database technology, and the current IT initiatives underway within the federal government and the US Navy. Geospatial Information Systems are discussed in detail and how they form the foundation for an improved facilities information system. A hypothetical example is developed to demonstrate concepts using a fictitious base and its efforts to improve its system architecture. Finally, real world examples of facilities system models are presented.

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1.0 Introduction

Successful Public Works Directors from all over the world will quickly admit that many daily challenges arise from having either too much or too little information. A decision making process relies on accurate information input for realistic decision output. Information Management quickly became a buzzword in the 1990's with the development of user-friendly database management software and powerful desktop computers. A distinction must be made between information and data. Data collection initiatives can become bogged down without clear direction as to how the data will be used to get useful information back to the requester.

Public works agencies have always been good repositories for data. The basement plan room of the facilities building contained a wealth of knowledge if one had the access, desire, and patience to sift through new drawings, old drawings, and missing drawings to find the piece of information required. To solve this problem of data retrieval, computer technology has been slowly introduced into facilities management organizations. Carrying promises of instant information access, computer software applications were developed and data was collected. The problem is that many of these initiatives were implemented independent of one another and no organization plan was in place from the beginning. The result has been a myriad of stand alone data repositories causing "islands of data," with little to no connectivity and little useful information output going into the hands of decision makers.

As time has pressed on into the 21st century, computer hardware, software, and networking technology have made systems integration a reality. The problem for most public works organizations, however, is that most engineers or managers did not have the computer expertise to update their systems on their own. Assistance was obtained from computer programmers and network administrators to complete a workable system architecture in their

organization. But as the complexity of these networks evolves, the divide between the engineer's and the network administrator's knowledge of the system has widened to the point where many engineers feel intimidated by the technology.

1.1 Objectives

This purpose of this paper is to provide a look at emerging network system technology for the use of public works managers. The paper will not serve to answer all the detailed technical questions involved in such a system, but it will cover the highpoints that a management level engineer should know about system architecture. This paper is specifically directed at members of the U.S. Navy Civil Engineer Corps who serve in Public Works Officer positions at Navy bases around the world.

1.2 Scope of Report

The scope of this report is to provide the Navy Public Works Officer a quick reference for learning about the new technologies in computerized infrastructure management and network system architecture. The report is divided into seven sections.

Section one contains an introduction to the subject and a statement of the scope for the report. Section two includes a discussion of Asset Management as a tool for public works managers and specifically describes some challenges faced for maintaining federally funded facilities. Section three covers the basics of internet, intranet, and database technology including current applicable Navy initiatives. Section four reviews a key element of infrastructure management software, the Geospatial Information System. Section five presents a hypothetical example of a small Navy base in its attempt to implement a revised system architecture for its organization. Section six includes examples of systems in place from various public works

activities. Section seven contains conclusions and recommendations for the Public Works Officer. A glossary of terms is included at the end of the report as well as a list of figures.

2.0 Asset Management for Public Facilities

The expansive infrastructure in the United States has directly contributed to the success of the American economy in the last century. A healthy, complete system of roads, water distribution, sewer facilities, and other networks has made it possible for our continued growth. There is an estimated \$20 trillion invested in infrastructure systems across the United States (Hudson, 1997). Most of these systems require large initial capital investment but the benefits are difficult to quantify in terms of return to the “consumer.” Because infrastructure projects are mostly funded by government agencies, funds for maintenance of the systems after initial construction have often been neglected. This section reviews some of the current asset management literature and how the concepts of asset management are applied through the use of software tools.

Many professionals in the field believe the health of our infrastructure is declining because of rapid economic growth but stagnant or declining maintenance funds. The American Society of Civil Engineers (ASCE) issued a Report Card of America’s Infrastructure in 1998. It concluded that 59% of urban and rural highways are in poor, mediocre, or fair condition. These local roads are critical for getting goods to consumers and delivering products to the marketplace. Additionally, 31% of all schools need extensive repair or replacement and 46% lack the basic wiring to support installation of computer systems. This is symptomatic of a pattern of under funding for school maintenance for the last several decades (ASCE, 1998).

Asset Management, sometimes referred to as Capital Assets Management Program (CAMP), is a relatively new way of looking at and managing infrastructure systems (NRC,

1998). The technique assists the engineer in using effective planning tools to manage infrastructure projects from the strategic level. Traditional engineering approaches to design solutions require extensive data about the system to determine the proper solution. This is certainly still the case when projects are identified for execution. Asset management at the strategic level involves looking at limited data and comparing the condition of components between separate systems to select candidates for repair and or replacement.

2.1 Asset Management Strategies

Asset Management by itself is a very generic topic. It could be referring to how one handles personal finances or how a business computes its bottom line. This line of thinking is also how it applies to public works systems. In the private sector, it is logical to compute the bottom line output of a process in terms of company profit or net income. In the public sector, benefits are often difficult to determine and even when they can be established, many public services are inherently money-losing propositions where no profit can be expected.

Many public works officials are reluctant to embrace asset management because they feel like they are doing it already as part of their job description. Simply put, asset management is more of an investment strategy than a new management tool. There are many successful network management tools in place throughout the industry. These tools manage a specific system such as a road network or a water distribution system. The challenge is in determining an investment strategy when looking at valid projects from two or more competing networks. An asset management system is not intended to replace the individual system tools, it should be used as the logical next step in an analysis process (Danylo, 1998).

A task force established by the American Public Works Association (APWA) reviewed the current state of asset management and listed three major benefits of an asset management strategy (Danylo, 1998):

- It will highlight the economic importance of the region's infrastructure. The public works manager will be able to show the value of the infrastructure network and the role that it plays in the overall regional economy. This provides an additional means of showing benefits for money spent on infrastructure systems.
- It recognizes the costs of infrastructure within a framework understandable to all stakeholders. Through modeling alternative funding levels, the public works manager can clearly show what effect the infrastructure system will have on the region in the future.
- It assists in controlling public works costs. With better and more detailed information available for decision making, the inevitable result is more effective decisions and a better use of available resources.

The APWA task force concluded by stating that more attention is warranted for asset management and that the APWA should embrace the concept. It recommends other agencies become more involved in supporting the principles and that the APWA Leadership Committee should provide additional funds and resources for study (Danylo, 1998).

2.2 Application Through Network Management Tools

Implementation of an asset management system will require a change in thinking for many in the public works industry. Management of roads and highways is often a leader for infrastructure policy due to the large amount of federal and state funding available for research. The American Association of State Highway and Transportation Officials (AASHTO) has embraced the asset management concept and determined some methods for use. AASHTO defines asset management as the “systematic process of operating, maintaining, and upgrading transportation assets cost effectively” (AASHTO, 1998). In addition, they are working to produce an Asset Management Guide, targeted for 2002, to assist agencies with implementation.

Asset management is being used in both the public and private sector for infrastructure management. Wal Mart uses an asset management approach to manage its real estate assets in evaluating weather to buy or lease property. The Virginia Department of Transportation closed a highway for 17 days instead of constructing a detour that would be in place for 2 ½ years after looking at the overall costs to highway users and their agency. Since the deregulation of the power industry, producers have had to look at their practices from a business management approach to effectively deliver power to consumers at the lowest cost. These are but a few examples of agencies taking a long term look at their methods to maximize benefits while minimizing costs (FHWA, 1997).

The concept of Asset Management is not new in Navy facilities management. The ideas behind the theory are similar to long range maintenance planning and life cycle management of facilities. Asset management is important, however, when discussing infrastructure management computer tools. The software of today is designed to give real time feedback to the Public Works Officer about what is happening on the base in terms of facilities. Without an effective data collection, analysis, and storage system, a public works program can quickly find itself buried in computer generated paperwork with no useful knowledge being gained. It is for this reason that an organized system architecture is critical to facilities managers. Without links between the systems in place, information will get lost, distorted, or not used at all.

2.3 Strategic Management of Navy Facilities

Implementation of an asset management system within the Department of Defense will be an uphill battle. Many barriers stand in the way to a successful program. These obstacles include training and retaining personnel to manage the software systems, obtaining network condition and inventory data, and selling the up front costs as a path to a long term benefit. Two

factors will be keys to success. Public Works Officers must change the way politicians and Base Commanders think about infrastructure work. Instead of always going for the short-term successes, planners must look to the long-term health of a system rather than always fixing the worst first. Secondly, traditional engineering practice must embrace economic reality. Network data is very costly to collect and maintain. Detailed data is not always available to make network level decisions about project funding and estimating. Engineers must be able to work with network level data to plan and prioritize projects then collect more specific data as projects get selected for programming and design (Hudson, 1997; FHWA, 1997; AASHTO, 1998).

The Department of Defense (DoD) is a huge real estate and facilities owner. The DoD spends \$100 billion a year to operate and maintain its infrastructure, which equates to \$70,000 per active duty troop (Adams, 1999). The challenge for the United States Navy Facilities Engineering Command (NAVFAC) is equally as daunting. NAVFAC manages some 140 base installations worldwide with land and facilities assets valued at more than \$140 billion (DefenseLink, 1999; Bilden, unpublished data). The leadership within the Navy is committed to making effective use of GIS technology and reaping the rewards that the power of information has to offer. In a 1998 survey, 100% of Navy activities report use of Computer Aided Drafting and Design (CADD) tools and 60% report use of a GIS (Center, 1998).

The National Research Council commissioned a study in 1998 on the problems of maintaining federal facilities. RADM (Ret) Jack E. Buffington, former Chief Engineer of the Civil Engineer Corps, chaired the committee. Their report titled Stewardship of Federal Facilities (NRC, 1998) summarized several key factors that have led to the deterioration of federal facilities:

- A focus on first costs by the funding process
- Inadequate funding for maintenance and repair (M&R) activities

- The aging of federal facilities
- The growth of deferred maintenance backlogs
- Lack of information to justify maintenance and repair budgets
- Lack of accountability for stewardship

This list does not detail every reason why federal facilities have deteriorated but does arrive at the root to most of the problems. The budget cycle has historically focused on first costs of construction in the approval process. Research has shown that first costs account for only 5-35% of the costs for the life cycle of a facility compared to 60-85% for operations and maintenance costs (Christain, 1997). Other research indicates funds for facilities M&R should be 2-4% of the replacement cost of the facility while most agencies report budgets of less than 2% are common. The average age of federal facilities is unknown but a large proportion is 40-50 years old. The large increase in base construction during World War II is the source for the increasing facility age. Lastly, the committee found a disturbing lack of information is being kept by agencies to justify their M&R budgets. When funding decisions are made by agency heads, the M&R becomes a low priority because facility managers do not have the information available to back up their case. As a result of this data void and a general lack of research in the field, the committee concluded "very little study of the costs and implications of deferring maintenance [has been done] and cost avoidance information is lacking" (NRC, 1998). Implementing information systems such as those discussed in this report can provide public works organizations with real time data to make daily decisions and to project future requirements.

A key concept discussed by the committee was the need for facilities managers to rethink their standard business practices. Most engineers feel the need to collect all possible data before making a decision on a course of action. The problem with this philosophy is that data collection is extremely expensive to execute and blind collection methods will inevitably lead to the demise

of an infrastructure management system (Smith, 1999). The committee presents a flow diagram of the traditional engineering decision process and the reverse engineering decision process, Figure 1. Note that the reverse process eliminates collecting unneeded data and thus avoids unneeded costs.

3.0 Intranet and Internet Basics

Before beginning any discussion of today's internet and intranet technology, some fundamentals should be reviewed. The primary goal of this report is to familiarize the Public Works Officer with the terminology and trends used in the industry in order to direct better decision making about managing their electronic information.

3.1 What is an Intranet/Internet?

The rapid advances in internet technology during the last half of the 1990's have reshaped the way information is managed for public and private enterprises alike. Internet technology is low cost and provides the latest functionality to its users. Until 1995, the client-server technology model (see definitions below) was the philosophy of choice for organizations. The internet provided the next logical step in this development. It provides a simple infrastructure that works on any computer of any kind, size, or location. The internet makes communications and information access transparent regardless of computer type (Rosen, 1997).

This section is intended to give the Public Works Officer some background before dealing with the specific issues of their own information management system. One recommendation must be made clear, however. Public Works Officers are not intended to be network administration experts or computer programmers, although some probably have learned enough to be both! The best advice, before beginning any major restructuring of an information system, is to consult with a systems analyst and/or network specialist. These professionals, with

your guidance as to content and data requirements, will make setting up a modern system architecture much more effective.

3.2 Database Management

The main reason to have an intranet or client-server relationship is to facilitate the exchange of data and information between users. The driving force behind this data movement is the database. As shown in Figure 2, the databases (or databases) residing on the corporate server is the fuel for making the applications run in an integrated client-server model. Recent improvements in database management software have been equally important to the growth of information technology as the internet itself. The database no longer relies on the computing power of a mainframe for most operations, as was the case twenty years ago (Simon, 1997). The influence of the internet in making data available to many users simultaneously has forced changes in how data is stored and information is managed. This section is intended to review some of the new concepts in database management and present some technologies that are making advanced information management possible.

3.2.1 Markup Language

A "Markup Language" is a series of identifiers that when linked to data or a document, tells the computer information about that data or document in order to expedite processing, display, or other functions. The term markup comes from the early days of written manuscripts. Ancient writers provided an indication of special meanings in the text or explanation around the edges of the text because parchment was so valuable. The notes were often written in a different color than the body of the text, usually a reddish color termed "terra rubrica." The author used this to bring special attention to certain points in the writing. As printing technology evolved, print editors would mark the original authors text with notes to the printing press as to how the

text was to be displayed through the press. This method of interpretation is easy for a human but explaining it to a computer is more difficult. Computers require the markup to be in a standard format that it can understand (Flynn, 1998).

Standardized markup languages have been developed to facilitate this process. There are two main classes of markup. Visual markup provides explanation as to how the text or data is to be displayed on the screen or on paper. Logical markup indicates meaning, reasoning, or purpose behind text rather than just the appearance. The Standard Generalized Markup Language (SGML) was the first standard developed. All other markup languages are subsets of SGML. Hypertext Markup Language (HTML) has become the language of choice for internet communication. The existence of standard HTML makes the display of web pages possible on various browsers and various computer operating systems. Extensible Markup Language (XML), discussed in more detail in Section 3.2.3, has been recently developed and shows promise in allowing greater data flexibility with its emphasis on logical markup vice visual (Flynn, 1998).

3.2.2 Data Access through Web Browsers

As a Public Works Officer reading this report, you may ask, "Why do I need to know about databases?" In the past, facility and infrastructure management software packages were written independently from one another. The way the systems read, stored, and allowed access to both data stored in the system and information output were often proprietary and incompatible between tools. This lack of connectivity often meant data needed to be entered numerous times between systems and output needed to be analyzed by hand to check for compatibility issues. In terms of computer implementation, offices had moved from a "pure paper" environment to a "computer assisted paper" environment (aecXML, 2000). The new internet technologies reduce

the requirement for expensive proprietary software for access to data. Web pages can be developed which actively pull data from various sources and allow access only to certified users. The web browsers themselves are free products and the development of web pages costs only a fraction of a typical complete software application and can often be done in house. So as a Public Works Officer, it is important to know that the face of data management is changing to a more open architecture.

Advances in internet technology and overall connectivity of users have made data access over the web easier. Web pages can be displayed in two forms. The page can be static, in that the information is updated by the author and posted on the web site. Any changes to the page need to be made manually and then republished on the web. Dynamic web pages draw their data from an existing database through an active link. For example, if a company had a current list of products that it wished to make available on the web, a web page could be developed to link to the company's database, conduct a search, find the pertinent data, and display the list through the web browser. This technology of dynamic web pages has greatly changed the face of web publishing and can reduce the problem of old data lying dormant on the web, which exists so often today. A good first look at internet and intranet database technology can be found in the book Intranet & Web Databases for Dummies (Litwin, 1997). This book is not a technical reference for computer programmers but does provide a good overview and some step-by-step examples, which are relevant to a manager exploring options for his or her organization.

3.2.3 New Trends In Data Management

Software companies have made great strides in improving the usefulness and power of database management systems. Advancements in both the user end and programmer side have changed the industry. The concept of a "Data Warehouse" actually originated in the 1970's

when centralized mainframe computers were the main data storage devices. Data would be periodically downloaded and placed onto tapes for storage, ostensibly to the benefit of people to use the data in the future. However, it was quickly discovered that data that is not at the fingertips of the user is not likely to be accessed. The 1990's version of the Data Warehouse is a systematic sequence of copying data from various data sources to make it available for analysis. In today's network environment, this means copying data from one location to another or writing software code that goes out and finds the data it needs, copying it into a second database. The Data Warehouse concept has additional value when integrated into an internet accessible data scheme. By copying data to a server with access to the internet, more sensitive data can be protected within the intranet allowing external access to the intended information only (Simon, 1997). This method demonstrates how the technology of routers and firewall systems apply to grant access to some and protects other data sources.

There are several key technologies that have contributed to the development of dynamic web pages. Less complex relational database software has become easier to use for "non-professional" programmers. Microsoft Access serves as an excellent relational database manager for smaller databases. Access is generally limited to databases of 1 gigabyte or less and it can only process 10 query requests at a time (Litwin, 1997). More complex database managers are SQL Server and Oracle systems. These programs generally require in depth programming knowledge to set up and maintain but are not restricted by such a size limit and can handle more search requests. A typical public works office should plan on using at least SQL Server if not Oracle, especially if a GIS is planned or in use. GIS programs are very data intensive and require management by a network systems professional. Microsoft Access can still be an effective front end for smaller management tasks and for linking information to the web. Oracle

databases have been widely implemented at Navy facilities and are used frequently with the MAXIMO software system. See Section 6.3 for further discussion of Oracle, MAXIMO, and GIS.

Another recent advance has been the growth of the Extensible Markup Language (XML). XML is seen by many in the information management industry as “a powerful key to smoothing communication among the hodgepodge of computer systems and software used by navigators of the world wide web” (Kalish, 2000). What XML provides that HTML does not is a logical interface to data. The language attaches “tags” to portions of data in the database, which can be used for more effective searches and information management. XML, in its root form, is not predefined. Business and industry leaders are working to develop standards that can be applied across the board. A new drive to develop XML for the engineering and construction industry began in August 1999 (aecXML, 2000). Bentley Systems, Incorporated, a software company responsible for the MicroStation products used throughout the engineering community, began a working group to develop aecXML (Architecture, Engineering, Construction XML). Their goal is to develop an XML schema aligned to A/E/C and facility management applications. The working group currently includes more than 450 companies worldwide as well as the federal Government Services Administration. The language is still in its preliminary specification stages and the release of Version 1.0 is expected by Winter 2000. aecXML can not hope to define all the terms and products in these industries. What it can do is provide a good basis for companies to begin information exchange and allow for more effective e-commerce. Public Works Officers should monitor this trend and look for policy guidance to be issued from NAVFAC or DON CIO.

3.3 Federal, DoD, and Navy Initiatives

One often confusing aspect of managing information technology within the Federal Government is the appearance of similar, and often competing initiatives to develop end products such as standards, applications, or models. From one aspect, this is a good problem to have because it means more minds are working on the problem. On the other hand, it also means a duplication of effort is being performed at a time when federal resources are limited. The Navy has not been immune to this problem and it is often difficult for the Public Works Officer to determine where they should look for the most up to date, relevant, and useful information. The following sections describe some of the Federal and Navy initiatives that are affecting facilities management information technology today. Note that due to the nature of this technology, the references listed below were current as of the date of this report and new initiatives may have been started to assist or envelop those listed below.

3.3.1 CADD/GIS Technology Center

The CADD/GIS Technology Center was formed with the mission to “Establish a multi-agency vehicle to coordinate CADD and GIS activities within the Department of Defense and with other participating governmental (federal, state and local) agencies, and the private sector. This includes setting standards, promoting system integration, supporting centralized acquisition, and providing assistance for the installation, training, operation, and maintenance of CADD/GIS and facilities management systems” (Center, 1999). Originally named the Tri-Service CADD/GIS Center, this organization has shifted its focus to invite other agencies outside of the DoD to participate and share information including the State Department, NASA, FAA, and GSA. Their website contains very good information on the basics of GIS and they are responsible for assembling the Tri-Service Spatial Data Standards (TSSDS). The TSSDS are

critical to producing GIS data uniformity to allow exchange between systems and eventually through the DoD Intranet. The Center recently won the Hammer Award from Vice President Gore for their work in developing and promoting CADD/GIS standards (Unattributed, Navy CE, 2000).

A CADD/GIS Center project of particular interest to facility managers is Project 96.015, Facility Management Standards (FMS). The objective of this project is to develop data content standards for installation facility life-cycle management, and civil works operations. The FMS will provide "a common data format for Real Property Inventory and event records (e.g., maintenance, management, operational) related to Spatial Data Standards (SDS) geospatial features and/or A/E/C CADD Standards Objects" (Center, 2000). The completed standards (Release 1.9) are available for download from <http://tsc.wes.army.mil/products/> at no cost. This download provides a desktop application that includes a browser for viewing and printing output as well as a generator for developing SQL code for the GIS database. The FMS could be enhanced by the development of aecXML if the federal government chooses to embrace the language.

NAVFAC has been on board with the CADD/GIS Center since its inception. They have also started an internal NAVFAC GIS Policy workshop to formalize the goals of Navy facility management with regards to implementing GIS. Currently, two of the prime points of contact within the Navy for GIS technology are Jeff Bryant (bryantjl@efdlant.navfac.navy.mil) and Dick Bilden (bildend@navfac.navy.mil).

3.3.2 Smartbase

The Navy's Smart Base Project was established by the 1997 Defense Authorization Act. Formed under the direction of the CNO's Director of Shore Installation Management (N46), the

Smart Base Project team was staffed by representatives from various Navy activities. The mission of the Smart Base Project is to identify, evaluate, and demonstrate cost saving technologies and business practices that can be used at Navy shore installations (Smartbase, 2000). The Smartbase initiative is far reaching and seeks to implement the goals of the Navy's Information Technology in the 21st Century master plan. The programs started by Smartbase impact the operational Navy community as well as the shore establishment.

Projects of particular interest include efforts in the Public Works area. One project is seeking to work with NAVFAC staff to develop a core package of software available to Public Works Officers for use in managing their facilities. The initiative seeks to migrate applications from Government produced (GOTS) to Commercial Off The Shelf (COTS) systems. Smart Base is working with NAVFAC to prototype Navy-wide rollout strategies of core applications and a consistent data architecture at Portsmouth, VA Naval Shipyard, Naval Station Pascagoula, MS, and Construction Battalion Center, Port Hueneme, CA. The current status of this project can be found at <http://www.n4.hq.navy.mil/SmartBase/home.html> under the Current Initiatives section.

3.3.3 Information Technology Infrastructure Architecture

A key to the broad goals of the Navy's information technology vision can be found in the Information Technology Infrastructure Architecture (ITIA) plan. This high-level guidance sets the stage for a multitude of technology applications within Navy bases around the world. The goal of the ITIA plan is to standardize the approach to which Navy activities design and manage their information architecture. The ITIA enables network planners and service providers to design, develop, and implement integrated network solutions that are seamless and cost effective (DONCIO, 2000). Without such a plan, the Navy runs the risk of falling into an information quagmire where there is no path from one information source to another, development projects

are not related, and exchange of electronic information is impossible. The final ITIA plan was signed in June 1999 and is available for download from <http://www.doncio.navy.mil/focusareas>.

The ITIA document contains useful network design templates for the Public Works Officer. The two templates, the Metropolitan Area Network and the Campus Area Network, are not specific to how to run a facilities management information system but are good references for managing the architecture of the entire base. These two documents are included as Appendix B and C of the ITIA document (DONCIO, 2000).

NAVFAC has also begun its own ITIA and Enterprise Architecture initiatives. The problems facing NAVFAC are symptomatic of the larger information management challenges. Several facilities management software solutions have been implemented at bases across the country over the past two decades. Now, with a mandate from the CNO to integrate technology solutions and to provide real time information feedback up the chain of command, NAVFAC must seek to identify, evaluate, and select the best complement of software for its bases. Figure 3, produced by NAVFAC, shows the variety of software tools that currently exist or are in development. As this figure suggests, software development has often been scattered and disjointed. A working group has been chartered to develop a standard Enterprise Architecture, which follows the guidance of the CNO as well as uses the standards sought after by the CADD/GIS Technology Center (Kleinwicks, unpublished data). These efforts are closely linked to the Public Works Smartbase initiatives mentioned above. The central point of contact for NAVFAC ITIA is Mr. Mark Kleinwicz. (KleinwicksM@navfac.navy.mil)

3.3.4 Navy/Marine Corps Intranet

The Chief of Naval Operations recently announced plans to seek an all-inclusive contract for operations and maintenance of Navy intranets around the world (Brewin, 2000). The project,

titled the Navy Marine Corps Intranet (N/MCI), seeks to hire a contractor to manage intranet networks for the Navy and Marine Corps. The general scope of the contract is “to develop a long-term arrangement with the commercial sector which transfers the responsibility and risk for providing and managing the vast majority of Department of the Navy (DON) desktop, server, infrastructure and communication assets and services” (NMCI, 2000). Specifically, the contract solicitation requires the operation of 253,000 fixed, 38,000 portable, and 80,000 embarkable “seats” which represent end user workstations connected to the intranet. The seats will be upgradable to provide higher computing power (such as for CADD or GIS) and classified material handling up to top secret. If implemented fully, this effort will cause a major shift from the current practice of hiring network specialists internally. It may prove to be an effective solution to the problem of retaining qualified personnel in these fields due to the pay disparity between Government and private industry. The success or failure of this effort will greatly affect how intranets are managed on Navy bases around the globe. The proposals were due 14 February 2000 and only large firms such as IBM and General Dynamics were expected to provide bids. For the most current information on the N/MCI contract, check with your local Information Officer or visit the N/MCI website <http://www.contracts.hq.navsea.navy.mil/nmci/>.

4.0 The Role of Geospatial Information Systems

Geospatial Information Systems (GIS) have rapidly grown in the last two decades and their use is certain to shape the way facilities are managed in the next century. With huge jumps in computer processing capacity and data storage technology, the information and power of GIS is available to more and more agencies nationwide. Because GIS technology is so new to many, it is misunderstood in some circles and misused in others. The power of information is very enticing to those looking to get a better grasp on their domain. Jack Dangermond, president of

Environmental Systems Research Institute (ESRI) said, "...knowing where things are and why is essential to rational decision making" (ESRI, 2000).

Government agencies across the country are taking a close look at using GIS technology within their organizations. "The acronym GIS has become a buzzword for technology." writes Nicholas Chrisman in his book, Exploring GIS (1997). A major hurdle in the implementation of GIS comes from the very basis of our decentralized government system. Because local and state governments have so much control of their own assets, universal application of data standards and technologies becomes extremely difficult. It is estimated that more than 80,000 agencies nationwide are involved with geographic information collection (Masser, 1998). Data and data standards are available from a multitude of sources and their use must be carefully screened for origin, accuracy, and applicability.

4.1 What is a GIS

Essential to any discussion of Geospatial Information Systems is a review of some key definitions and concepts. Because GIS is so new, there are no theories imbedded in decades of past practice. There are as many different definitions of what a GIS is as there are agencies who make use of the systems. A generic definition is "a system of hardware, software, data, people, organizations, and institutional arrangements for collecting storing, analyzing, and disseminating information about areas of the earth" (Chrisman, 1997). The broad nature of this definition brings to light the multitude of applications where a GIS can be used. It is not a system limited to use in facilities management; on the contrary, its roots are widespread across fields such as forestry, environmental studies, fire and rescue services, and military battlefield management. Along those lines, note that the "G" in GIS stands for Geospatial instead of Geographic for discussion in this report. The use of GIS technology, once linked closely to the geography of the

earth, has progressed to the point where it is no longer bound by such a constraint. Geospatial is a more holistic term that encompasses more information types than those tied only to a point of land (Perdue, 1999).

Before looking at what makes up a GIS, it is handy to look at the other tools available that preceded the widespread use of GIS. The following systems are listed in order of increasing technical complexity and effectively, the order of their development in time (Bruner, 1999).

- CAD – Computer Aided Drafting
- CADD – Computer Aided Drafting and Design
- CAM – Computer Aided Mapping (No imbedded intelligence)
- AM-FM – Automated Mapping-Facilities Management
- LIS – Land Information System
- GIS – Geospatial Information System

Chrisman proposes there are six functional rings that make up a GIS: measurement, representation, operations, transformations, institutional context, social and cultural context. (Figure 4) The representation of the system as a series of rings demonstrates how each level is essential to the development of the next and the information within each is a part of the larger ring. To develop the data portion of a GIS, there are three component types: space, time, and attribute. The space component defines an item's location within the system such as an x,y,z coordinate or longitude and latitude. The time component dates the input data, which is very important to determining accuracy of current conditions and predicting conditions forward from a point in time. The attribute component includes the physical properties of the item such as diameter of pipe, material, design flow, etc (Chrisman, 1997).

The GIS database is made up of several standard building blocks. A point, or node, is just that, a point in space. Points can link other objects, such as arcs to form chains for analysis. Arcs are lines between two points. The line can contain vector attributes such as magnitude and

direction of movement and is not required to be straight. Polygons are areas bounded by arcs to form a closed loop. Calculations using the polygon can be made such as area, what polygons border this one, etc. (Chrisman, 1997). Perhaps most important to a GIS system, and the feature which distinguishes it from basic mapping tools, is the link to tabular data.

The data will be grouped into thematic layers allowing a better analysis of one network versus another. For example, one layer may be the storm sewer system while another layer may contain road information. By looking at these two data sets together, planners can execute work more efficiently by linking needed storm sewer repair projects that are in the same location as road repair work. Linking an object to a relational database “behind the scenes” allows analysis of the network that would not be possible with just a mapping tool. As another example, in an urban environment, traffic patterns can vary drastically during the day. Emergency crews accustomed to taking one route can likely find it blocked with traffic. By linking the GIS data between 911-Emergency and traffic control centers, the real time volume and flow data being monitored in the traffic center can be used to better direct crews to a location.

4.2 GIS Pitfalls

To many agencies, GIS appears to be the savior for their management woes. This one tool can track their systems, tell them where repairs have to take place, budget for future years, and cook their breakfast to boot! Reality, is of course a rude fact of life. Information systems such as GIS are very maintenance intensive and are really never “complete.” Dr. Roger Smith states that there are two primary killers of information management systems. The first is personnel turnover. When people leave, often the corporate knowledge about the physical network or the computer tool leaves with them. The computer system architecture is very complex in most GIS applications. A trained systems analyst is critical to maintaining data

validity and understanding some of the less obvious relationships. The second killer is trying to collect too much data. It is impossible to cost effectively collect all the data needed for detailed engineering analysis on all the segments of a network at once (Smith, 1999). The engineering profession must change its paradigm to be able to make decisions about project priority and planning with limited network level data. More detailed data can subsequently be collected or validated when it is needed for design.

There are other key factors to be considered when weighing how to apply a new GIS tool. Proper evaluation and implementation of a system are critical to a successful GIS. The information managers must be able to assess the accuracy of the database, the efficiency of the system, and its effectiveness in serving the purpose (Chrisman, 1997). Up front dedication of resources is essential. The list of resources includes computer, financial, and human. Planners must realize that the up front cost of computers is usually much lower than the salaries required to maintain the data system during its life cycle. Additionally, the data acquisition and conversion costs will greatly outweigh hardware and software costs (Huxhold, 1991).

Geospatial Information Systems must be used properly within the framework of the agency. Information flow within an agency must be carefully analyzed to determine the origin, destination, and path of all data requirements. In a classic text on the use of GIS systems, Huxhold describes this thought process with a typical government agency information pyramid. (Figure 5). Agency requirements should be studied to ensure, for example, that the policy level is not requiring some data that has no relevant use in the operations level (Huxhold, 1991).

4.3 Federal GIS policy

Early in the development of GIS technology the federal government realized the potential impacts of geospatial data. In 1989 the Office of Management and Budgets (OMB) expanded

the authority of the Federal Interagency Coordinating Committee on Digital Cartography (FICCDC) to include data standardization. This committee led OMB to produce Circular A-16 in 1990. OMB A-16 established the Federal Geographic Data Committee (FGDC) to coordinate the development of spatial data standards through technology development and promote interaction between various federal agencies to share their data and knowledge. An important feature of OMB A-16 was its broad agency coverage, and included the Department of Defense. At the same time as the establishment of the FGDC, the Mapping Sciences Committee of the National Research Council was the first to coin the phrase "National Spatial Data Infrastructure." Further stressing the importance of spatial data, Executive Order 12906 titled, "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure," was issued 11 April 1994 by President Clinton to "strengthen and enhance the general policies described in OMB A-16" (Masser, 1998). In a recent press release on the subject, Vice President Gore stated that improvements in accessibility to geospatial data will allow "more control, more information, more decision-making power into the hands of families, communities, and regions [and serve] to give them all the freedom and flexibility they need to reclaim their own unique place in the world" (FGDC, 1998).

4.4 The Military's Impact on GIS

The military has had a strong influence on the development of computer technology in general and specifically GIS use. In 1942, the Army had a significant need for developing up to date artillery range cards for use in the field. The process was very math intensive and required many computations to complete the work by hand. The Army Ballistic Research Laboratory created ENIAC (Electronic Numerical Integrator and Computer) in 1945, which was America's first digital computer. Computer technology continued to advance through the 1950's

contributing to the development of atomic weapons and the space program. From 1960-1972, project CORONA utilized imagery from newly orbited satellites for use in intelligence gathering. The first photo reconnaissance satellites developed from this project. During the Vietnam War, Operation Igloo White used GIS technology to monitor troop movement. By placing sensors along the Ho Chi Minn trail, the Army and Air Force were able to detect movement and direct attacks from a central command center with digital mapping technology. All of the services made extensive use of GIS technology during Operation Desert Storm to track friendly and enemy troop movements and, more importantly, give real time information feedback to field and unit commanders, not just the command center General (Perdue, 1999).

The US Army Corps of Engineers Construction Research Lab (CERL) was seen as a leader in GIS Software development during the very early years. They developed the Geographic Resources Analysis Support System (GRASS) in 1985. This package can be considered one of the original desktop computer GIS applications. In the early 1980s, CERL approached the fledgling software industry to tailor a system toward DoD's emerging needs. But at the time, commercial GIS capabilities were very costly, were only available on expensive mini-computers, and database creation generally ran into hundreds of thousands of dollars. By the early 1990s, the software industry's GIS efforts had matured and began to overtake CERL's efforts in releasing GRASS updates. The last version of GRASS released by CERL was 4.2 in 1992. ESRI, who has emerged as a leader in GIS software, has partnered with CERL to support users needing to move data between GRASS and ESRI software, such as ArcView and ArcInfo (CERL, 1999).

4.5 GIS in the Navy

Like most facilities management agencies coming up through the decades of the post World War II era, the most consistent source of information in an organization was the engineer who had been there the longest. This person was the “go to guy” when a tough utility locate was required or when someone needed to know when the last time a segment of road was paved. The file drawer of drawings was a good information source as well but wading through the stack in the basement of the facilities maintenance building was never a sure solution. With advances in computer technology effecting the entire industry, the Navy was certain to take advantage of the improvements.

In the early 1990's, the Navy contracted for the development of the ALFA/APMM software package. The ALFA (Activity Land and Facilities Assets) portion of the system housed an advanced graphical mapping system with features such as regional maps, building information and use, structure condition and others. The APMM (Activity Planning and Management Model) originated as an electronic master plan package. It evolved into an asset management software system capable of actual data analysis instead of display only. The ALFA/APMM package can be classified as an AM-FM system (refer to system types discussed earlier), short of a fully capable GIS. These systems have quickly been outdated since their highpoint in 1996. Mr. Dick Bilden, GIS Manager for NAVFAC states the “world has progressed far beyond the ALFA stage...of a few years ago” (Bilden, unpublished data). Commercial GIS systems are now prevalent throughout Navy activities worldwide. In a recent survey, 75% of Navy activities that operate a GIS are using ArcInfo and ArcView (Center, 1998).

The leadership within Commander, Naval Region Japan has taken a big step forward towards implementation of a regional GIS tool. Mr. Ayman El-Swaify, CADD/GIS Manager for

PWC Yokosuka is in the middle of the development process. His three person staff has spent \$3.3 million in implementation since the project's inception in 1996. Combined Fleet Activities Yokosuka is a large facility covering 568 acres located just 43 miles south of Tokyo, with a daytime population of over 23,000 personnel. As an example of the base's complexity, the GIS project is in year 3 of 5 for its utility survey. This is further proof that the data collection and maintenance for GIS applications is very costly. The completed GIS will include coverages for other bases in the Japan region as well as Yokosuka. Mr. El-Swaify states that his biggest obstacles have been limited staffing, timely funding, numerous related initiatives throughout the Navy and other DoD forces, and their remote location relative to the United States (El Swaify, 1999).

Another major GIS project underway is located in Pearl Harbor, Hawaii titled the Regional Shore Installation Management System (RSIMS). Hawaii contains numerous Navy and other DoD installations. Land management is critical on the island because real estate is so valuable and resources are more costly due to the Hawaii's distance from the mainland. The islands, with their extensive network of military facilities, are a prime location for a regional GIS tool. A key challenge for the project has been linking the outputs from existing installation management systems (such as MAXIMO) to the GIS server and database. The data transfer makes use of the Navy LAN and intranet but working with data compatibility issues between applications has been difficult. Data security is a key obstacle, and links to the internet have not yet been finalized for that reason. Figure 6 is included to show a screen shot from the RSIMS package. The screen shows various utility locations, color-coded by type. Not shown is the tabular data behind the map, which contains the critical information for analysis. The RSIMS is also discussed further in Section 6.3 (CNRH, 1999).

The Navy is working to finalize its policy statement for implementation of GIS. Such a policy statement is important to clearly define the goals across all installations so duplication of effort is minimized. A NAVFAC GIS working group recently completed a Draft Policy Statement (NAVFAC, 1999), which sets forward some intentions. In short, the Navy's goal is to follow the direction of Executive Order 12906 and make use of the TSSDS as universally as possible. The policy statement also recognizes that GIS development is critical to the future success of Navy facilities management, hopefully setting the standard for buy in from Navy leadership. Sharing knowledge, data, and resources will be critical to success and NAVFAC will seek to eliminate redundant development efforts and make maximum use of COTS products. A key benefit of complete CADD/GIS implementation is a paperless design process. Vice President Gore has been leading efforts throughout his term to improve government efficiency and make paperless government processes a reality (NAVFAC, 1999).

4.6 The Future of GIS

Efficient and effective management of information systems will be critical to the sustainability of Navy asset management into the next century. The Pentagon currently estimates is has a 23% excess base capacity throughout the services (Adams, 1999). The outputs and analysis of Geospatial Information Systems will play a pivotal role in the decision making process of which ones go and which ones stay. The base that can accurately inventory its assets has a handle on operations costs and is making continuous improvement to its infrastructure is much more likely to remain in operation when compared to a base that is fixing the worst first and operating on crisis management principles. Effective decisions can not be an expected output without valid information on the input side.

GIS tools have some huge potential benefits and equally huge challenges facing them. Objectivity is a major benefit of GIS (Chrisman, 1997). GIS technology allows for the presentation of comprehensive information from a myriad of data sources. Additionally, regional information systems will eliminate duplication between agencies, making effective decisions easier due to needing only one source. On the negative side, increased efficiency often leads to lost jobs and resources as processes are centralized. There is the legal issue of public domain access and the impacts of the Freedom of Information Act on federal GIS data, including the DoD and the Navy.

The Navy and NAVFAC have taken some important steps towards integration of GIS philosophies into their operations. The power these systems present to the user is very enticing. With power, often come more challenges, however. Brian Purdue of the CADD/GIS Technology Center reminds us that “GIS is *built* not *bought*.” Navy leadership support must be strong and steadfast throughout the system’s implementation and operation phases. The leadership within NAVFAC must maintain its commitment to universal GIS implementation and be an advocate for its continued use through management support, training, and funding.

5.0 A Proposed System Architecture

The following section will provide an example situation of a Public Works Department working to improve its system architecture. The facts in this example are all fictitious, and any similarities to existing Navy facilities are coincidental. The example will present some background information about the base and its public works organization, the current facilities management systems in use and how they are linked, development of an implementation plan, and a proposed system architecture. The facts in this case are relatively straightforward and

simplified to illustrate a point. Real implementation of change to a system architecture is complex and requires expertise, resources, and time.

5.1 Background Information

Wilmington Naval Facility is located in Coastal North Carolina on approximately 25,000 acres of land. The main mission of the base is the maintenance of aircraft engines and airframes of propeller driven aircraft. The base has a 7,500-foot runway to support flight operations. Other tenant commands also reside on the base including an Aviation Mechanic "A" School and Marine Corps small boat unit. The base has a daytime population of 10,000 people. The base has electricity supplied from the local community utility company but runs its own wastewater and water treatment plants.

The Public Works Department (PWD) employs approximately 300 people. A wire diagram organization chart is included as Figure 7. The PWD has its own in house maintenance forces but recent attention has been given in Congress to renewing the A-76 Outsourcing program for facilities work tasks. The base has some on base housing units but the Housing Officer is not in the PWD chain of command. A small fire department is maintained on base, mainly for airfield response. A security force is provided by a contracted security company and is augmented by Navy Master-At-Arms personnel.

5.2 Current Legacy Systems

Several independent computer systems have grown in the PWD within the past 15 years. The systems are fragmented, however, and many man-hours are spent compiling data from one system to compare with output from another. Additionally, the multiple data entry sources have resulted in errors in the validity of data when comparing one version with another. The following paragraphs describe the legacy systems within each division. A wire diagram of the

systems within each Division is included as Figure 8. Figure 9 provides a legend for interpreting both the existing and proposed system architectures.

Contract Administration and Construction Management: These two divisions use the same LAN and are located Building 1000. All computers in the division are Macintosh products. The database was developed locally by senior staff within the division and the quality of the data is generally high and frequently updated. Data input is done from within the two divisions while output is primarily in the form of paper reports to the PWO/ROICC and LANTDIV Contracts Division.

Facilities Support Contracts: This is a small division with no existing LAN or email capability located in Building 844. The Contract Administration Division forwards all contract paperwork by printout. Most people in this division work in the field with daily inspections of service contract providers such as housekeeping, grass cutting, garbage collection, etc. Timely and accurate entry of inspection results into the Contracts database has been a problem.

Design: This division is staffed with design engineers in specific disciplines. The office is located in Building 1000 with Planning and is running a LAN with IBM compatible machines. The typical user has a Pentium III desktop processor with 17" monitor. The office is currently running AutoCAD 14 and is in the process of digitizing old drawings for use in planning and design as well as producing all new drawings with CADD. A small ArcInfo GIS system is in place which was the deliverable product of a ground water monitoring control project. The PWD Headquarters staff is also located in this building and is connected to the Design LAN. They operate no specific database and are mainly email users.

Maintenance: This is the largest division within the PWD employing approximately 150 people. The division works out of 5 separate buildings around the base. The Work

Control/Planning & Estimating Branch have a LAN in Building 2105 which is running a COTS work management program. The P&E branch also uses the Long Range Maintenance Program (LRMP) GOTS software to aid in planning future maintenance projects. The shops buildings and utilities locations (water and wastewater plants) have no existing LAN. There are scattered 8386 speed IBM clones through the shops but they are all stand-alone. It is unknown what, if any, data is stored on these machines. Vehicle Maintenance and Dispatch operate out of Building 55. They too have stand-alone older IBM clones and operate two separate GOTS products for managing the vehicle fleet. Note in Figure 8 that all shops and utility locations are not specified on the diagram for simplicity of display. The computer assets in each building are typical as indicated.

Planning: This small division is located in the same facility as Design and is connected to their LAN. They are responsible for real estate management, producing and updating the Base Master Plan, and interfacing with the surrounding community on land use issues and emergency response planning. Special funding has come available through the Navy for implementing a GIS tool for managing real estate usage and Air Installation Compatibility Use Zones (AICUZ). The division head had a study completed for implementing the GIS within a year and has asked the PWO/ROICC for approval to move forward.

5.3 Developing an Implementation Plan

The PWO/ROICC has the following goals for improving the enterprise architecture within the Department. The various computer networks need to be connected and integrated by an intranet to use a common data source for common data. She would also like to make maximum use of browser technology and avoid the addition of cumbersome GOTS products. An active database link is desired for access to information through the web. One application of

this link is to provide potential construction contractors to access on line plans and specifications for upcoming work and to view the final contract price and scope of work for recently completed projects on the base. In order to follow Presidential and NAVFAC paperless design goals, the network should allow for a paperless process from plans and specifications development with CADD, to advertising through the internet, to solicitation and bidding for the contract.

The first step to success is development of an implementation plan. The Executive Steering Committee should commission a working group to look at the issue. The work group's charter should request two main products; 1) Deliver an assessment and summary of current system architecture; and 2) Develop a Requirements Document for the new architecture. The working group should consist of volunteers from each of the six divisions within the PWD, preferably with some computer networking knowledge but not necessarily the low level network specialists. Parties from outside the Department should also be invited to join such as Financial Management, Fire Department, Security, and Housing. The work group should feel free to get input from others and ask for formal nomination of additional members if they see fit.

The key product of the work group will be the Requirements Document (RD). The RD is not unlike any planning document used for software development or other systems analysis. The document should include the following sections (Rosen, 1997):

- Goal of project
- Concept Statement
- Scope of Project
- Benefits
- Client Demographics (internal and external)
- Current Client Requirements (internal and external)
- Future Client Requirements (internal and external)
- Resource Requirements

The final report from the working group should be presented to the ESC for approval. For system changes of this magnitude, the working group should recommend a partial

implementation first to show the results of the plan. The plan could be executed within one or two functional areas, for example, to limit the up front cost during the trial phase. Once the trial phase is completed, the ESC can elect to continue with full implementation, make changes to the trial section, or defer the project into the future. (Smith, 1999)

5.4 Proposed System Architecture

Figure 10 provides a sample architecture for WNF Public Works. The proposed solution is a schematic of the physical network. An additional goal of the working group would be to further define the Enterprise Architecture, which would include an analysis of the process flows within the organization and how the physical network allows those processes to happen. This phase is critical to implementing successful change as there is no "cookie cutter" network to fit the processes within a given public works entity. NAVFAC is striving to create a standard Enterprise Architecture (see Section 3.3.3) for the use of Navy Public Works managers worldwide but that effort was incomplete at the time of this report. For this example, the following specific changes and features were recommended to the divisions:

General (Applies to All Divisions):

- Reuse existing LAN and hardware where possible (including Macintosh systems)
- Internet Explorer will be the standard browser for web access.

Design:

- A review of the existing Environmental GIS shows the base map is excellent. It can be used for the building of further coverages
- This GIS will be the central source for cartographic data within the Public Works Department. A full time position should be dedicated to constructing the GIS.
- Conduct a separate study of access requirements for GIS data. Plan for data storage using Oracle DBMS.

Planning:

- Do not begin separate a GIS project. Direct funding to support building of GIS under the Design Division to include real estate and AICUZ coverages.
- Provide access to disaster response plans and other contingency plans through the PWD Intranet. With approval of Base CO, make plans available to the public through internet posting.

Maintenance:

- Work with Design in collecting data for GIS.
- All satellite Shops offices will connect by phone line to PWD Intranet.
- PC's in shops are not reusable, procure new equipment and laptops for field personnel.
- Continue use of COTS work control product. Plan for migration to MAXIMO for PWD's after its release (planned 2001). Contact manufacturer of current software about data properties and data dictionary availability.

FSC:

- All field personnel will be issued laptops.
- Inspections will be entered into laptop and can be sent to server over any phone line or by connecting once back in the office.
- Access to contract information will be done using the browser through extranet access to the Contract Administration server.

Construction Management:

- Convert data for storage to Oracle DBMS
- Design change requests, RFI's, and other information can now be done electronically to Design branch through Intranet.
- Procure laptop computers for inspectors for entering daily reports and other information while in the field.

Contract Administration:

- Potential contractors can access plans and specifications through internet.
- Establish a Data Warehouse for contract data including upcoming plans and specifications, recently completed work, and other metrics of interest.

Headquarters:

- Ensure Systems Administration is appropriately staffed.
- Follow developments of N/MCI and other initiatives and respond accordingly.
- Develop a Data Warehouse for information repository. The Data Warehouse should contain critical performance indicators, regular reports from internal and external sources, and other information.
- Coordinate with other Base agencies for data compatibility issues and ensure all internal programs are using predefined Navy/NAVFAC Standards (i.e. for CADD/GIS)

Base Activities Outside PWD:

- Develop dynamic website for public access showing current projects on base, upcoming major events, closure notifications, etc.
- As new facilities and roads are constructed, link digital data to existing Emergency Services GIS. Updates will likely have to be done manually if the two GIS systems are not compatible.
- Link Emergency Services through extranet to distribution of all road closure and utility outage requests generated by contractors or internal repair forces.
- Link Fiscal Department through extranet to Headquarters for budget reporting, quarterly accounting, requests for funds, etc.
- Link Housing Department through extranet to Design Division GIS for housing assignment maps, occupancy reports, etc.

This example demonstrates the power an up to date network can have on the functionality of an organization. Completing changes to an existing system architecture can be a difficult experience. Changes can encounter resistance for a variety of reasons. Refer to Section 7.0 for a discussion of some common obstacles.

6.0 Example Systems

The following sections provide some example system architectures from various sources. The format of each is not identical and the content of the figures has not been modified from its original source.

6.1 Texas A&M University Physical Plant

The Texas A&M Physical Plant conducts all facilities operations for the College Station campus. The organization is responsible for more than 200 buildings and employees approximately 1,200 people. Figure 11 presents a diagram of the Physical Plant's facilities management system processes. The figure represents a centralized approach where a variety of systems feed information into the central facilities management software. Many of the data sources are indeed linked by automated processes but others require manual updates. The department's integration of GIS has been excellent. For example, all of the trees on campus are cataloged and cartographically located within the GIS. Each tree is identified by type and the linked tabular data includes specific data such as pruning requirements, nutrition needs, and other information that would normally have to be looked up manually every time a problem was noted with a tree. This model was obtained from Mr. Mark Herro, Assistant Director for Telecommunications, Texas A&M Physical Plant.

6.2 InfraManage GIS-based Infrastructure Management System

The InfraManage system is a prototype tool developed by three engineering researchers in Champaign County, Illinois with funding from the Illinois Department of Transportation. The model was developed to show how a GIS tool can be used to facilitate better management decisions. Figure 12 shows their conclusion of a system design for highway infrastructure management. As was noted earlier in this report, transportation research is often on the leading edge of infrastructure technology due to numerous federal and state funding sources. The figure shows the simplified relationships of the systems involved and the direction of flow through the GIS application. Through their sample application, the researchers were able to demonstrate the power of the GIS tool to perform investment trade off analysis, coordinate project implementation, collect highway performance information into one location, and how a single tool could tie data together from five different specific infrastructure management systems. Successful systems such as this one are important for demonstrating the worth behind the investment in GIS. This model was obtained from a published research report (Gharaibeh, 1999).

6.3 Commander, Naval Region Hawaii, Pearl Harbor

The Commander, Naval Region Hawaii was selected as a test bed for the new Regional Shore Installation Management System (RSMIS) and Regional Shore Infrastructure Planning system (RSIP-Link). These tools will serve as true Asset Management systems for regional commanders to enable them to roll up information from a variety of data sources and perform analysis. Figure 13 shows the basic network system relationships behind the RSIMS. The power behind this system is its use of browser technology for viewing information. The browser is used both for access to GIS information as well as MAXIMO, the central facilities

management software (CNRH, 1999). Figure 14 shows how the individual systems cover facility information needs. MAXIMO provides operational data and includes daily work management systems, which would be used by the individual public works department or center. RSIMS ties GIS capabilities to the MAXIMO data with future planning requirements and is used by both the PWC, contract planners, and engineering staff, for project development. RSIP-Link is intended as a macro-level planning tool for use by regional commanders, which will allow access to real time data from all operational levels. NAVFAC intends to make RSIMS and RSIP-Link the standard for Public Works Centers throughout the Navy and eventually will be implemented at smaller Public Works Departments. This system architecture which includes MAXIMO, RSIMS, and RSIP-Link will very likely end up a key element within the NAVFAC Enterprise Architecture plan, which is still under development. (See Section 3.2.3) This information was obtained from Mr. Mark Kleinwicks and Mr. Dick Bilden, NAVFAC, Washington, D.C.

6.4 Navy Public Works Center, Yokosuka, Japan

Public Works Center Yokosuka, Japan has been aggressively tackling tough system architecture issues. They have begun a comprehensive GIS program for the base and hope to roll up all bases in the Japan region (see Section 4.5). Figure 15 shows their path toward an integrated system architecture. The department is continuing to implement the MAXIMO software but has encountered numerous problems with connecting to existing legacy data. Their systems are a mix of COTS and GOTS products which is typical for many Navy bases. This information was obtained from Mr. E.C. Morley, Information Systems Director, PWC Yokosuka, Japan.

7.0 Conclusions and Recommendations

This report has looked at some of the fundamental forces affecting facilities management information technology. Like the entire information technology field, the facts in this report will likely be overtaken by improvements in technology and methodology within a short time frame. This section summarizes some of the key points from the report and makes recommendations for the Public Works Officer.

The planned implementation of the Navy / Marine Corps Intranet could fundamentally change how network systems are maintained in the Navy. Depending on the final scope of the contract, network management may become contracted for the Navy, allowing greater access to technology and expertise. Unanswered questions include how far will the intranet management extend based on availability of funds for the contract? Will Naval Construction Force units be included for their stateside facilities? The Public Works Officer should be fully aware of upcoming N/MCI work including the effects on base infrastructure (new fiber optic requirements, for example) as well as its effect on the internal Public Works operation.

The Navy's information management policy is rapidly evolving as the technology continues to change. Obtain the most recent policy guidance available before making any changes. Visit the DONCIO website (see Section 3.3.3) for the final version of the ITIA and ITEA documents. Contact NAVFAC or the local EFD Public Works Divisions for the most up to date NAVFAC Enterprise Architecture documents. Be sure to maintain contact with the local Chief Information Officer as they may access to new information.

Include a GIS as a part of any infrastructure management application system. An accurate GIS will provide a common datum from which to build upon. Almost all information in the facilities world has a cartographic base. Before deciding weather an existing GIS should be

kept or rebuilt, analyze the accuracy of the base map. If the base map is not accurate, all future links to the bad data will be suspect. Carefully consider contracting options when establishing a GIS. The new system must comply with CADD/GIS Center standards for data format and the structure should be consistent with NAVFAC policy. GIS projects are long term. Public Works Officers should make the point to Base Commanders that these systems are ever changing and a long-term resource commitment is required.

Changes to infrastructure information systems often face many obstacles. These obstacles can be grouped into three classes: people, organizational, and developmental. People issues include personal conflicts, communication problems, the tendency for turf protection, and the human nature to resist change. An attitude of "if it was not developed here, it can't be any good" often prevails when comparing GOTS to COTS products. Organizational challenges include the size and structure of the agency, personnel turnover rates, and political challenges such as funding. Lastly, technical issues such as the complexity of the problem, availability of commercial products, personnel skills and training availability, and proprietary software challenges exist. Many software manufacturers are reluctant to provide details of the internal data definitions or code to limit access by the user. Navy Public Works Officers must realize that many of these challenges are real on board our bases. There is also an underlying fear that increased technology leads to decreased jobs, especially in the service fields such as the PW Shops. (Smith, 1999)

Hire a systems professional. This statement does not imply that there are not highly qualified network managers and computer programmers within the DoD or the Navy, exactly the opposite is the case. If a qualified government employee is available, certainly take full advantage of their expertise. This statement is meant more to discourage the Public Works

Officer from laying the future of the department's information technology on the junior CEC Officer in the Wardroom. Analyzing, modifying, and maintaining a system architecture is extremely complex and the task should be tackled by people well versed in the field. Data security also becomes a central issue when you allow access through an intranet or internet. Ensure classified data is separated according to standards and recognize the risks associated with allowing internet and intranet access to your data servers.

Asset Management is an effective concept for managing our infrastructure. As technology increases, the ability of Public Works officials to cost-effectively collect and store relevant data on their networks will also increase. This data needs to be used within a process to make effective decisions based on the information the network management systems can provide. Computer assets and personnel skills are a key to this success as well as changing the way engineers make use of the technology available to them. Trained staff must be maintained by agencies in a period of high turnover for employees with information management skills. Lastly, the politics of infrastructure management must look beyond the near-term solution toward a goal of long-term success.

Navy Public Works Officers can not avoid the fast approaching effects of technology on the facilities management industry. The technology, tools, and skills are available in the marketplace today to vastly improve base operations. Implementing these changes can not be done haphazardly. The leadership in NAVFAC and the Department of the Navy, Chief Information Officer have taken the right approach in developing implementation standards and models for execution. To deliver the best facilities service possible to the Fleet in the 21st century, we must embrace 21st century technology and make it an everyday part of the operations process.

Glossary

Asset Management: A methodology to efficiently and equitably allocate resources amongst valid and competing goals and objectives (Danylo, 1998).

Client-Server Model: An arrangement of computer servers and desktop computers or terminals within a local area network. See Figure 2. Departmental servers let the PC's in a work group share facilities like modems, faxes, printers, or databases. Corporate servers handle most of the central agency data storage (Rosen, 1997).

Data Warehouse: The coordinated, architected, periodic copying of data from various sources, both inside and outside the enterprise, into an environment optimized for analytical and informational processing (Simon, 1997).

Enterprise Architecture: An information technology enterprise architecture integrates mission and operations requirements into the design, selection, and operational processes of information technology structures. The enterprise architecture is more specific to a particular group of activity processes (such as facilities management) than the general infrastructure architecture plan (DONCIO, 2000).

Extranet: A hybrid of the internet and intranet. Allows access to information contained within the intranet through an internet connection. Specific security rights are assigned to those accessing through an extranet (Rosen, 1997).

Firewall: The firewall is a computer/router placed between the agency's computer network and the internet. All internet access and emails pass through the firewall, which checks for viruses and grants access (Rosen, 1997).

Hub: The hub is an active physical layer device and is used to connect the wiring closet to the desktop computer. It has evolved into an intelligent switching device that can route traffic vice sending all signals to all end users (Rosen, 1997).

Infrastructure: The system of public facilities, both publicly and privately funded, which provide for the delivery of essential services and a sustained standard of living. This interdependent, yet self-contained set of structures provides for mobility, shelter, services, and utilities (Hudson, 1997).

Infrastructure Architecture: An information technology infrastructure architecture is an integrated framework for evolving or maintaining existing information technology and acquiring new information technology to achieve the agency's strategic goals and information resources management goals (DONCIO, 2000).

Internet: A collection of computers located all over the world that anyone can access. Graphical User Interfaces (GUI's) called Web Browsers allow people to access these computers without having to learn the specific system's computer code. The internet uses TCI/IP as its main communication protocol (Rosen, 1997).

Intranet: A network of computers within an organization. Only people within the organization can access information contained inside the intranet. An intranet can consist of both LAN and WAN connections (Rosen, 1997).

Local Area Network (LAN): The LAN is a network arrangement in which one computer is directly connected to another computer. The network users own the medium (Rosen, 1997).

Public Works: The physical structures and facilities that are developed or acquired by the public agencies to house governmental functions and provide water, power, waste disposal,

transportation, and similar services to facilitate achievement of common social and economic objectives (Hudson, 1997).

Relational Database: A relational database is a collection of data items organized as a set of formally-described tables from which data can be accessed or reassembled in many different ways without having to reorganize the database tables. Common fields are used to link one table to another, allowing efficient access. Database technology is further discussed in Section 3.2.

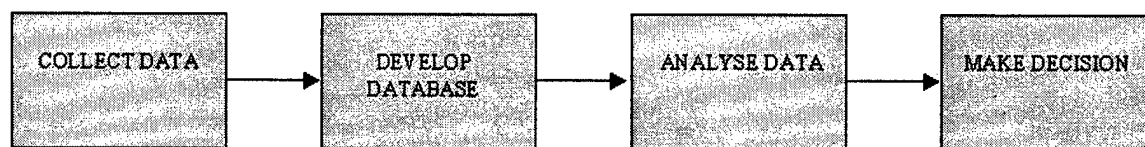
Router: The router is an active and intelligent network node. It participates in the management of the network, providing dynamic control over resources and supporting system engineering and maintenance activities. It can incorporate bridging functions and may serve as a limited form of hub (Rosen, 1997).

TCI/IP: Transmission Control Protocol/Internet Protocol: The family of data communications protocols used to organize computers and data communications equipment into computer networks. For an internet or intranet, TCI/IP manages information flow from one computer to another. TCI/IP was originally developed by DoD to link strategic missile systems (Rosen, 1997).

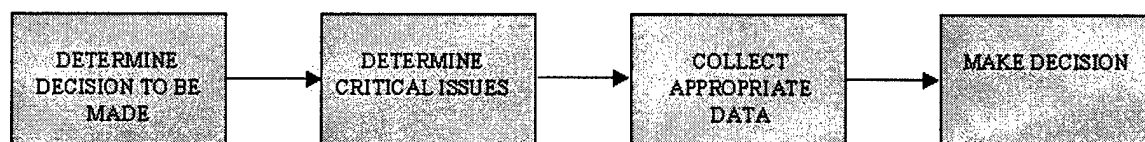
Wide Area Network (WAN): The WAN is a network arrangement in which computers are connected through a communication service provider. The service provider owns the medium. For some Navy facilities, the Navy still owns the communication lines on base but they are not directly controlled by the PW organization (Rosen, 1997).

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TYPICAL ENGINEERING PROCESS



REVERSE ENGINEERING PROCESS

Figure 1: The Engineering Process [From (NRC, 1998)]

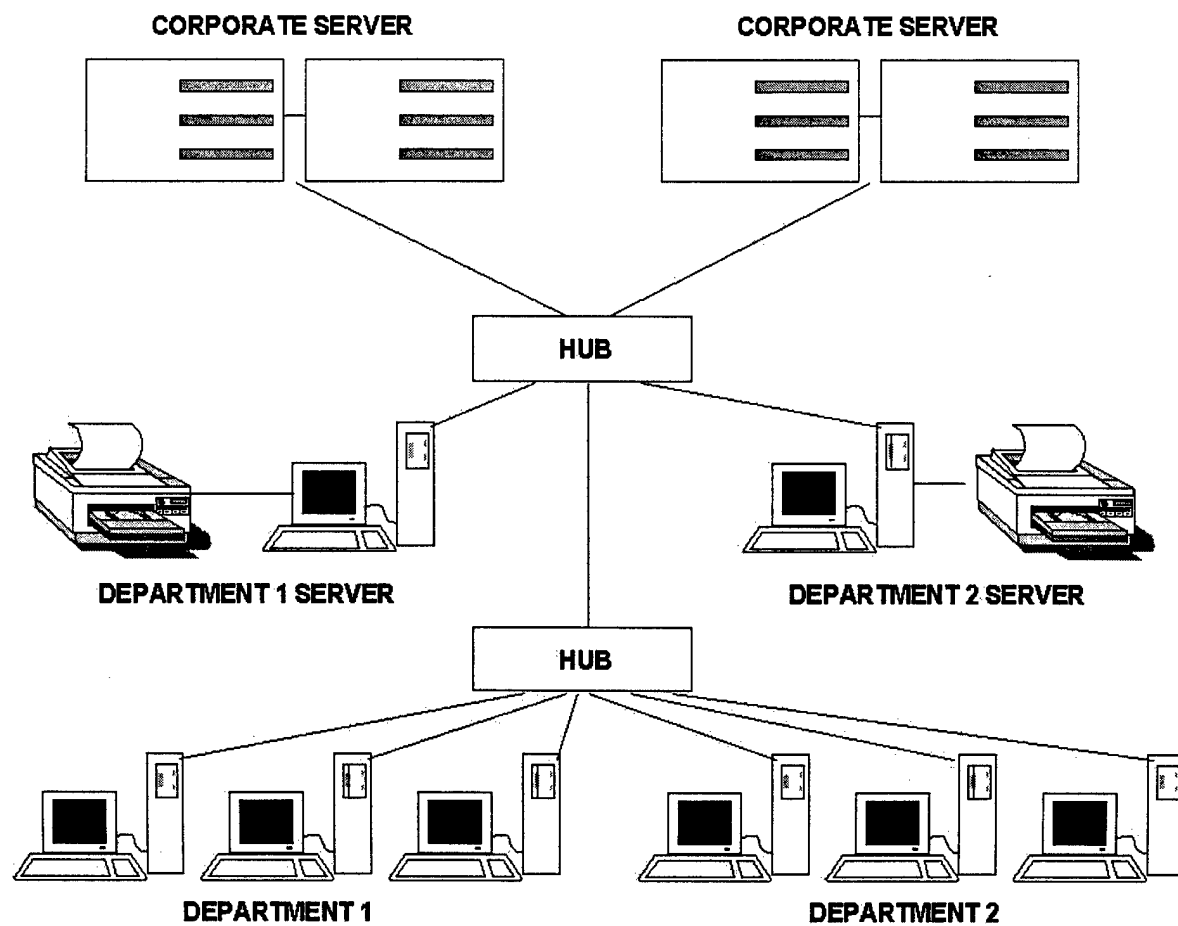


Figure 2: The Client-Server Model [From (Rosen, 1997)]

Sample of Facilities-related Systems at Installations

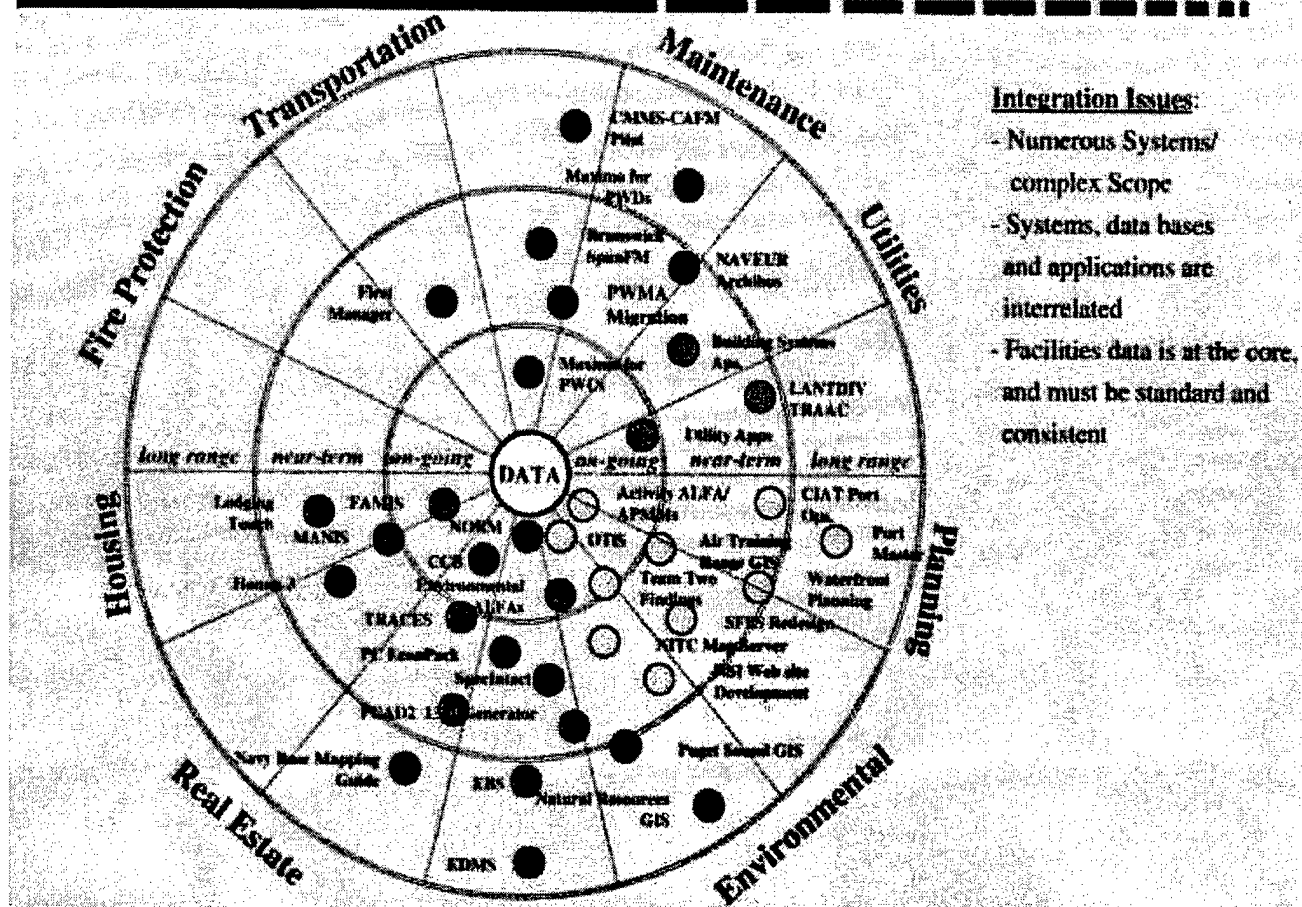


Figure 3: Navy Facilities Related Systems [From (Kleinwicks, unpublished data)]

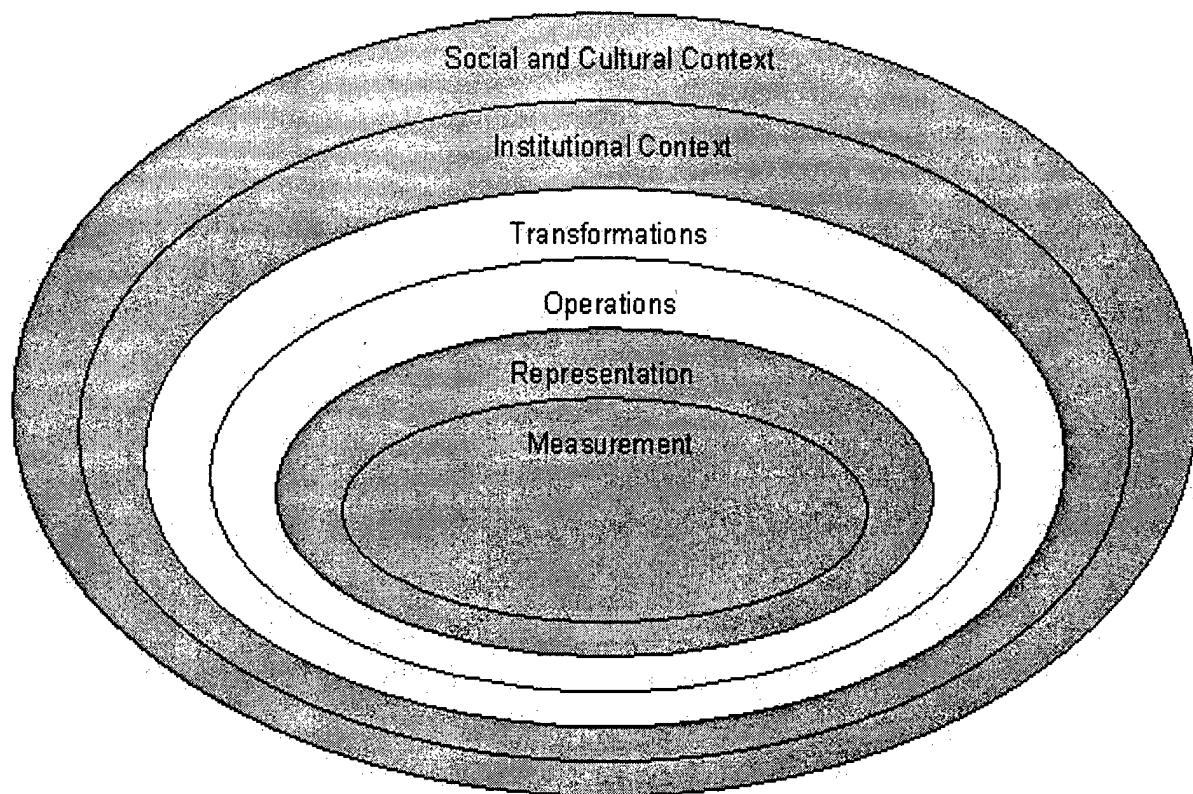


Figure 4: The Rings of GIS [From (Chrisman, 1997)]

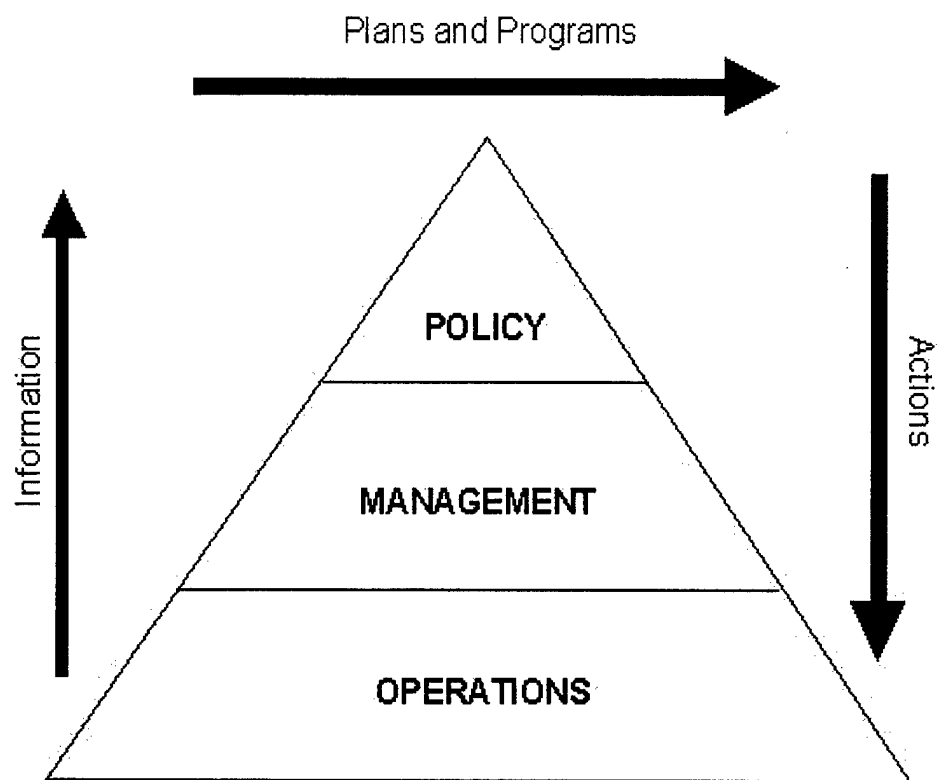


Figure 5: The Government Information Triangle [From (Huxhold, 1991)]

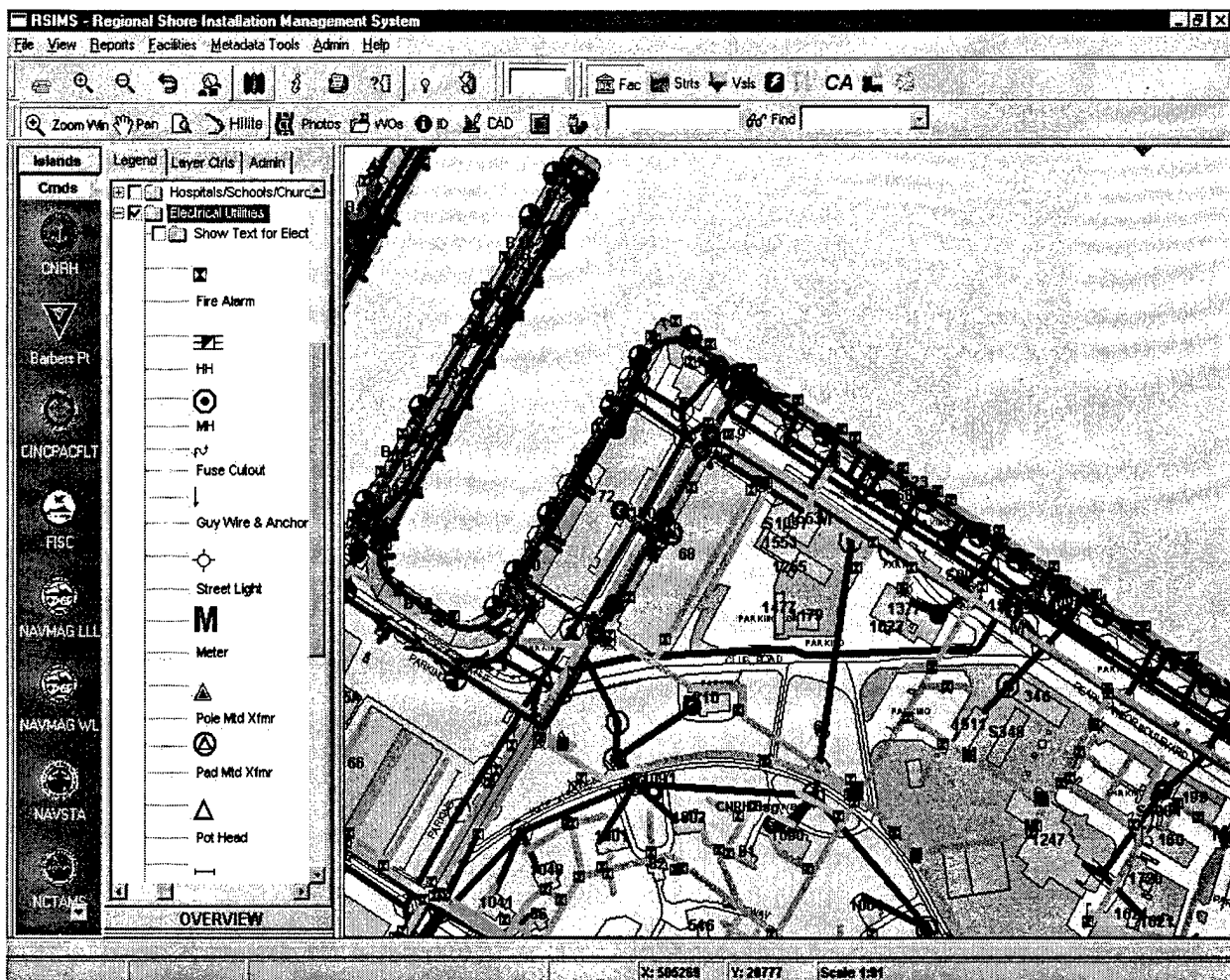


Figure 6: Image from RSIMS System [From (Commander, Naval Region Hawaii, unpublished data)]

Wilmington Naval Facility Public Works Department

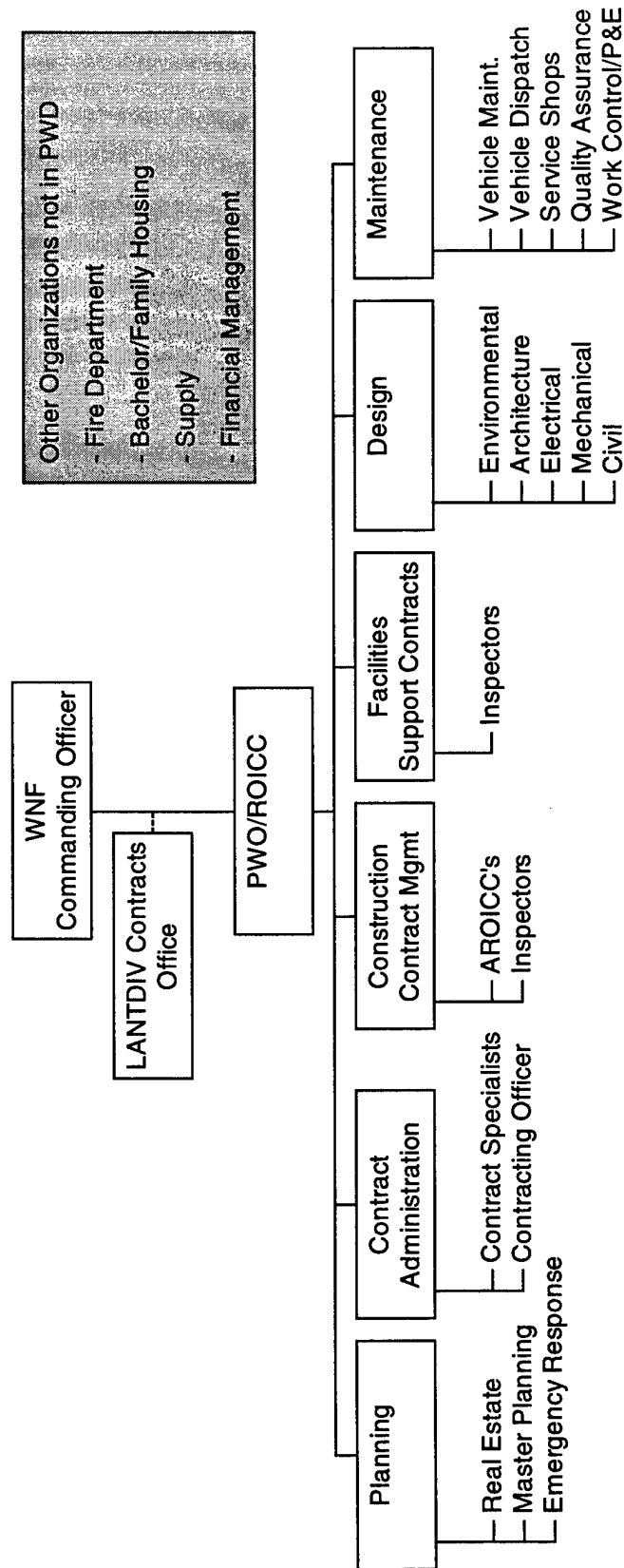


Figure 7: WNF Organization Chart

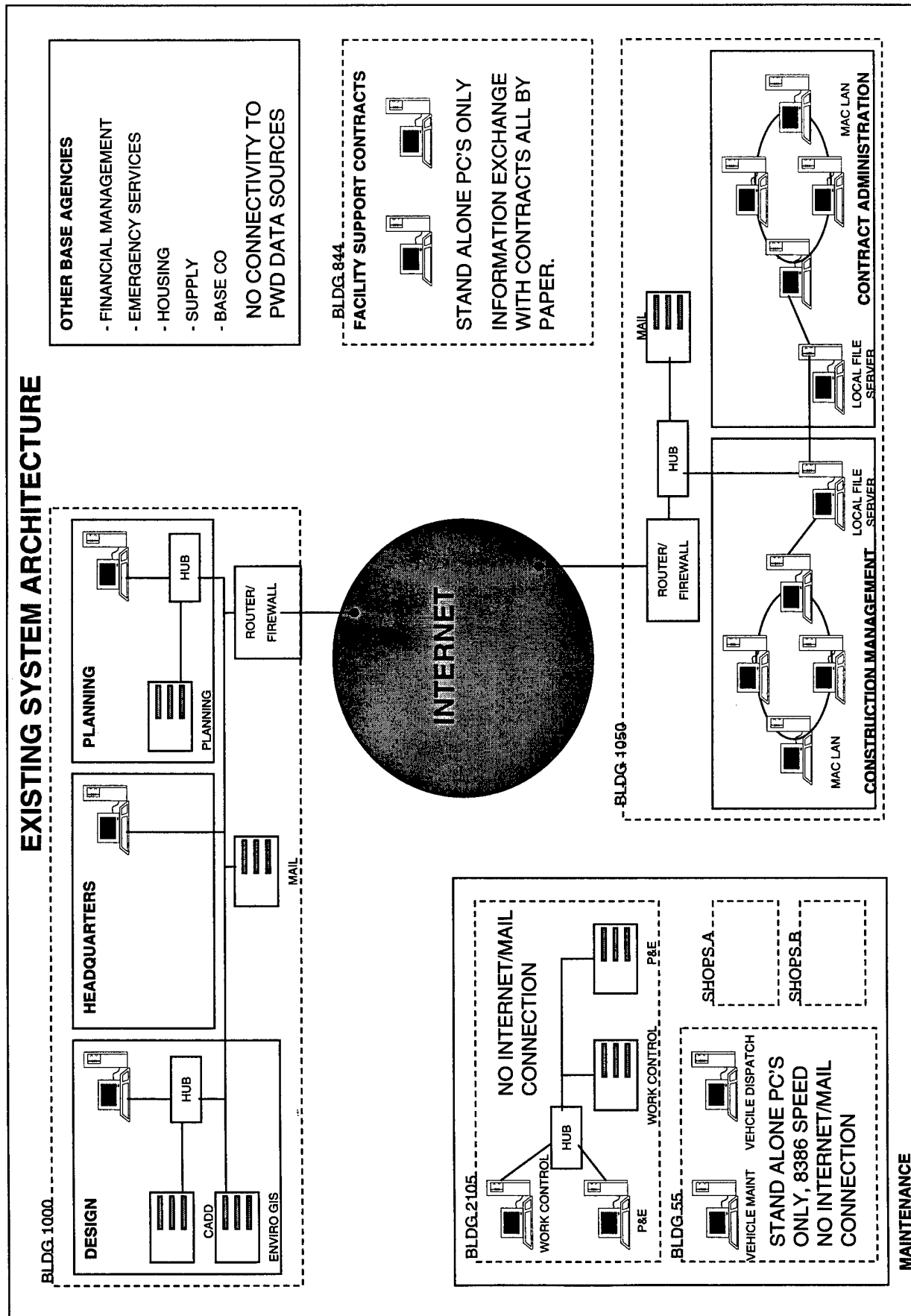
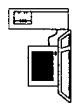


Figure 8: WNF Existing Legacy Systems

Legend for Figures 8 and 9. See report text for detailed definitions.



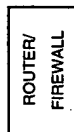
End User Desktop Computer. Can Serve as a Local File Server. One icon can represent more than one system.



Server. Designed for large data storage and multiple user access.



Portable Computer. One icon can represent more than one system.



Router/Firewall system hardware.



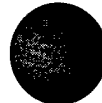
Hub for connecting network entities.



Fixed Wiring Connections.



Dial In Network Connections.



The Internet. Connections shown from various network equipment. Connections are made using various media types.



The PWD Intranet. User access defined within the department.

Figure 9: WNF Systems Legend

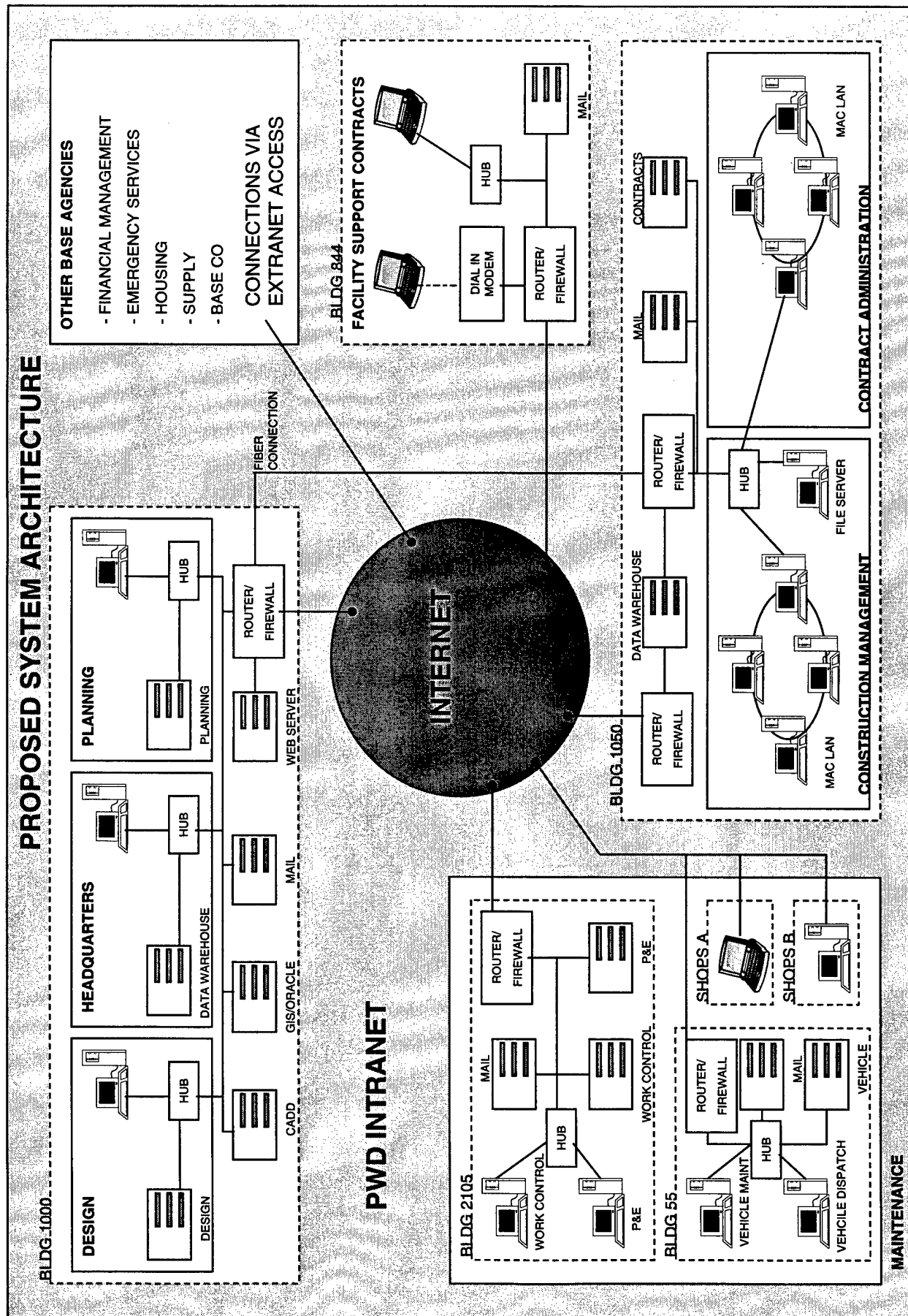


Figure 10: WNF Proposed System Solution

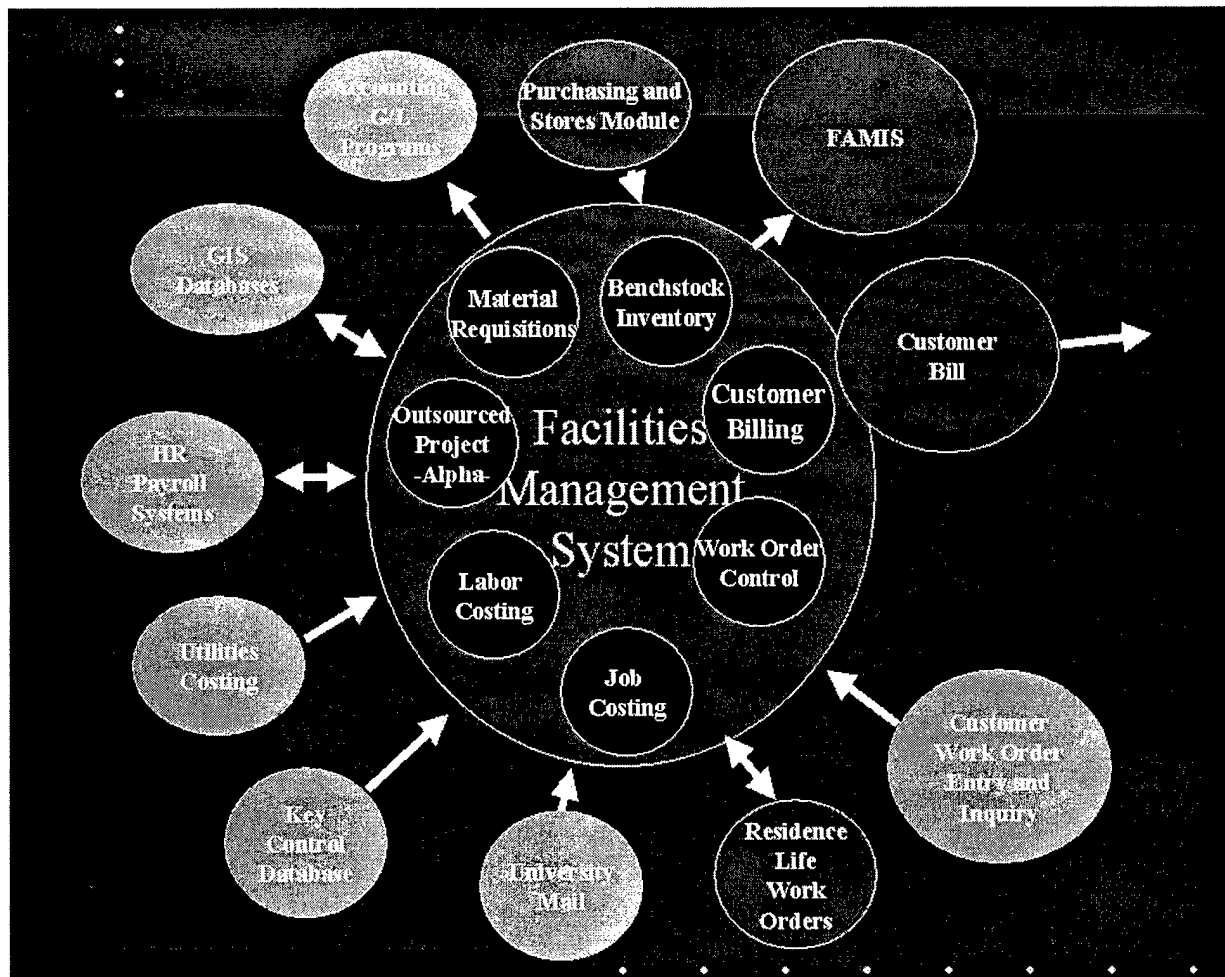


Figure 11: TAMU Facilities Systems Model [From (Herro, unpublished data)]

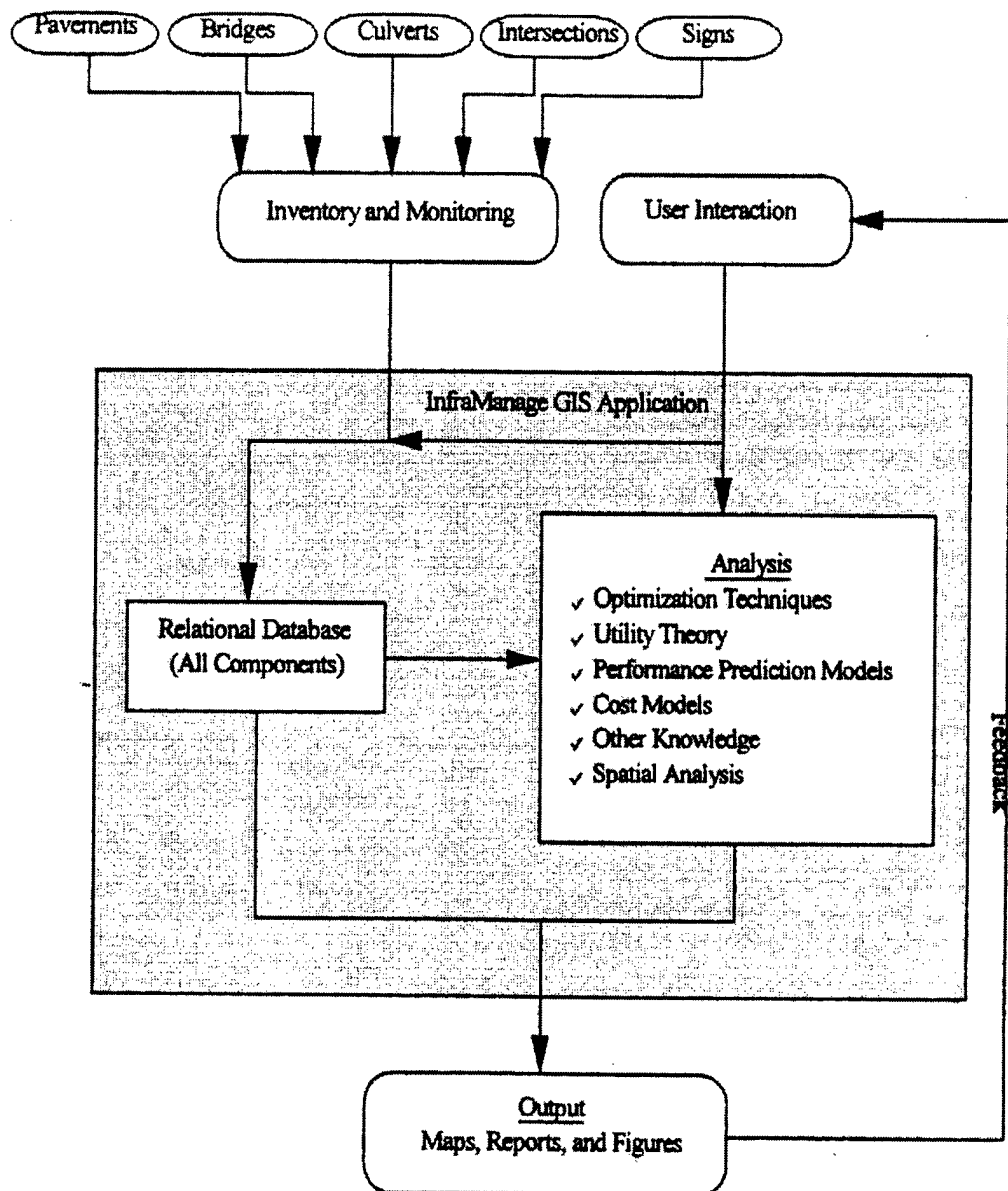


Figure 12: InfraManage Prototype GIS System Model [From Gharaibeh, 1999)]

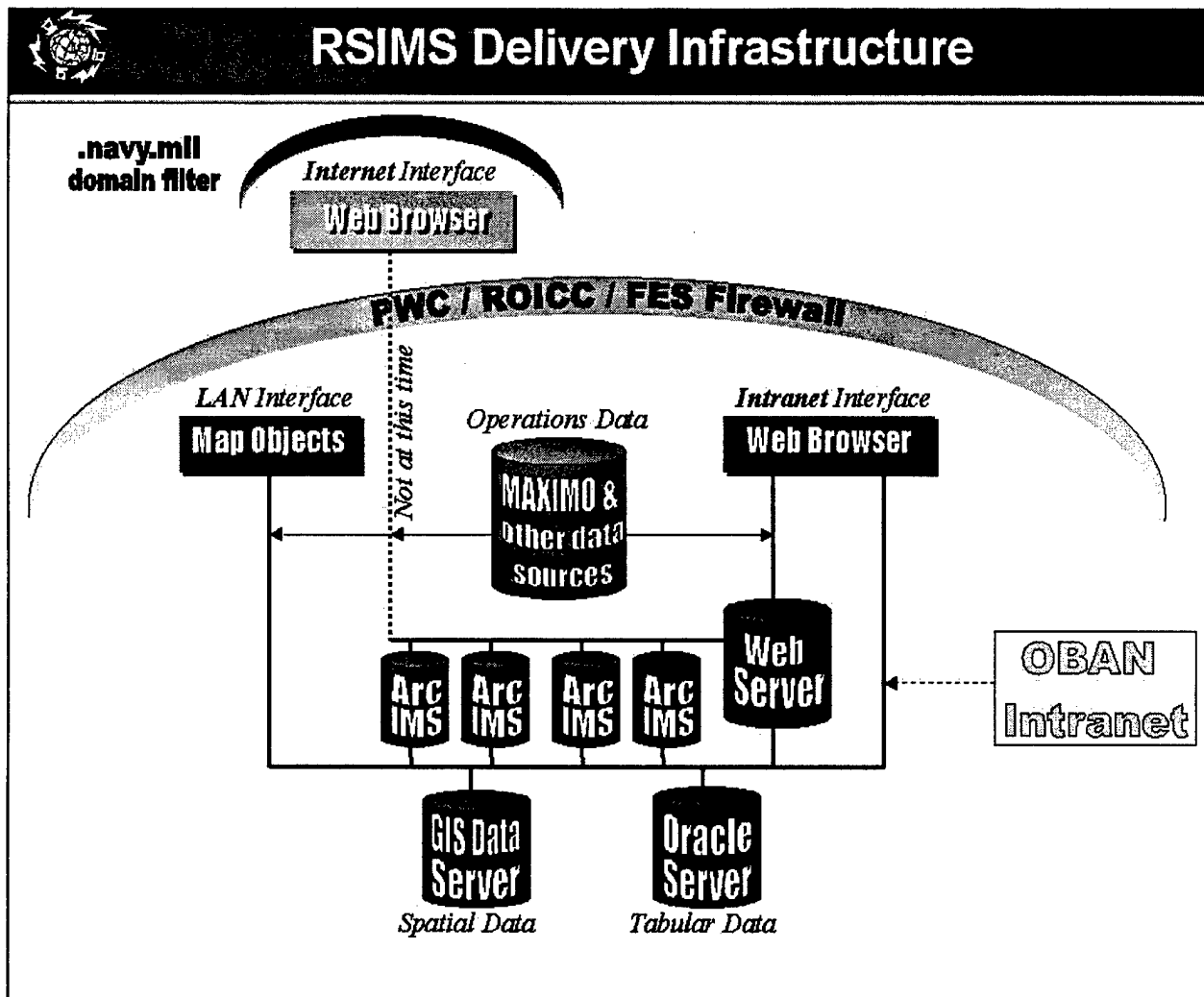


Figure 13: CNRH Facilities System Model [From (Commander, Naval Region Hawaii, unpublished data)]

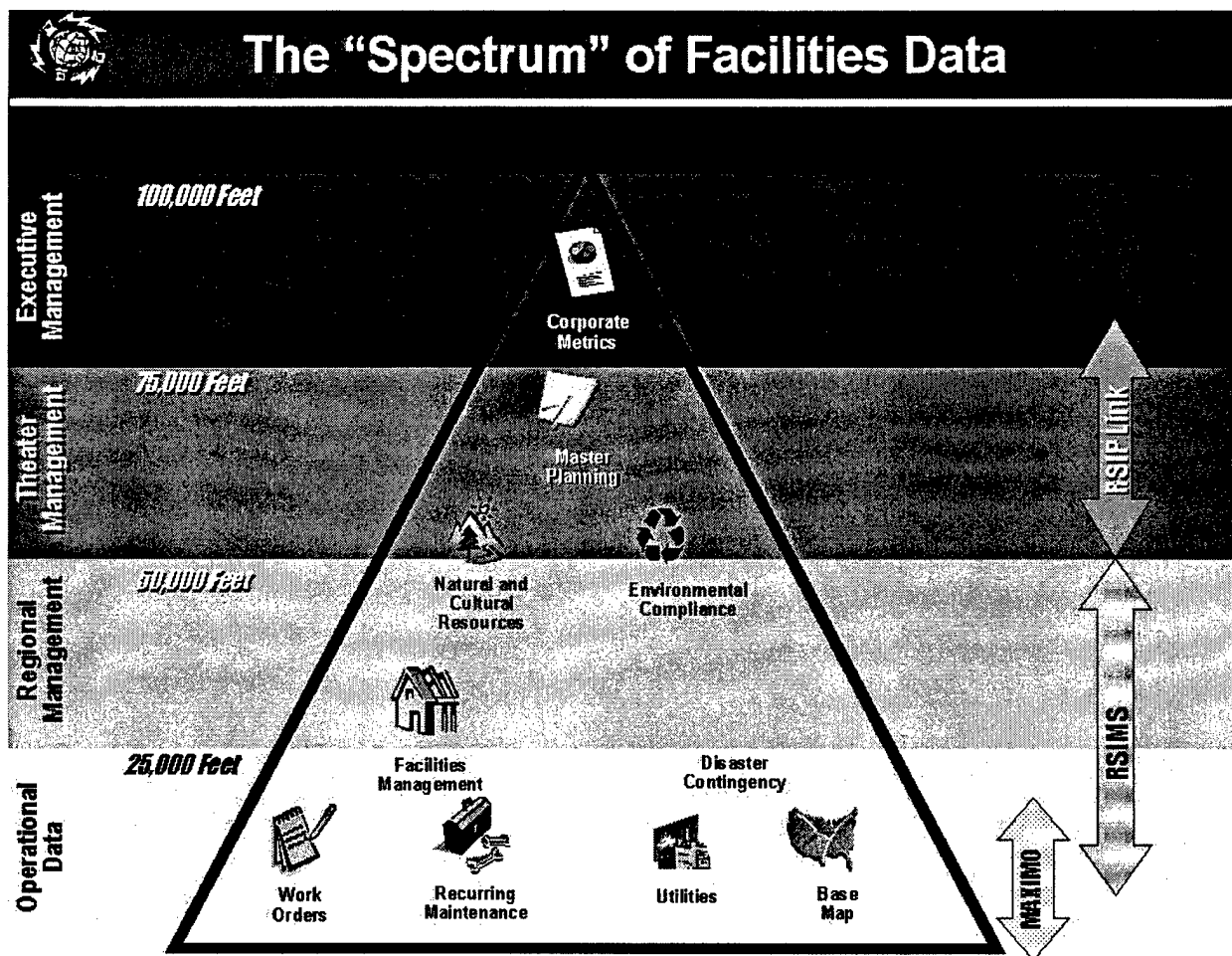


Figure 14: How Tools Cover the Information Spectrum [From (Commander, Naval Region Hawaii, unpublished data)]



Yokosuka's Chronology

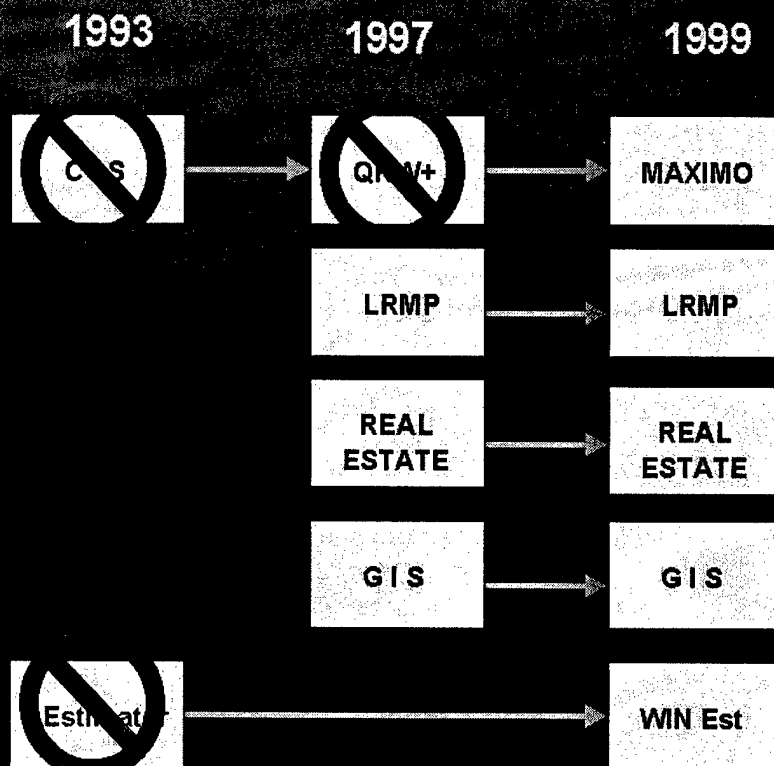


Figure 15: PWC Yokosuka Facilities Systems Model [From (El Swahify, unpublished data)]

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